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Lee et al.

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(54) **NONVOLATILE MEMORY DEVICE IN THREE-DIMENSIONAL STRUCTURE WITH A STRESS REDUCING MATERIALS ON THE CHANNEL**

(58) **Field of Classification Search**
USPC 257/315, 324, E29.309, E21.209, 257/E21.423, E21.662, E27.103, E21.645, 257/E21.68, E21.21, E27.098
See application file for complete search history.

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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Primary Examiner — Khaja Ahmad

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(51) **Int. Cl.**
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H01L 27/115 (2006.01)
H01L 45/00 (2006.01)

(57) **ABSTRACT**

A nonvolatile memory device includes a substrate, a stacked structure with conductive materials and first insulating materials and the conductive materials and the first insulating materials are alternately stacked on the substrate, and a plurality of pillars in contact with the substrate and the pillars extend through the stacked structure in a direction perpendicular to the substrate. The device also includes information storage layers between the conductive materials and the first insulating materials, and second insulating materials between the first insulating materials and the pillars.

(52) **U.S. Cl.**
CPC **H01L 27/11582** (2013.01); **H01L 29/792** (2013.01); **H01L 45/1233** (2013.01); **H01L 45/1253** (2013.01)

10 Claims, 36 Drawing Sheets

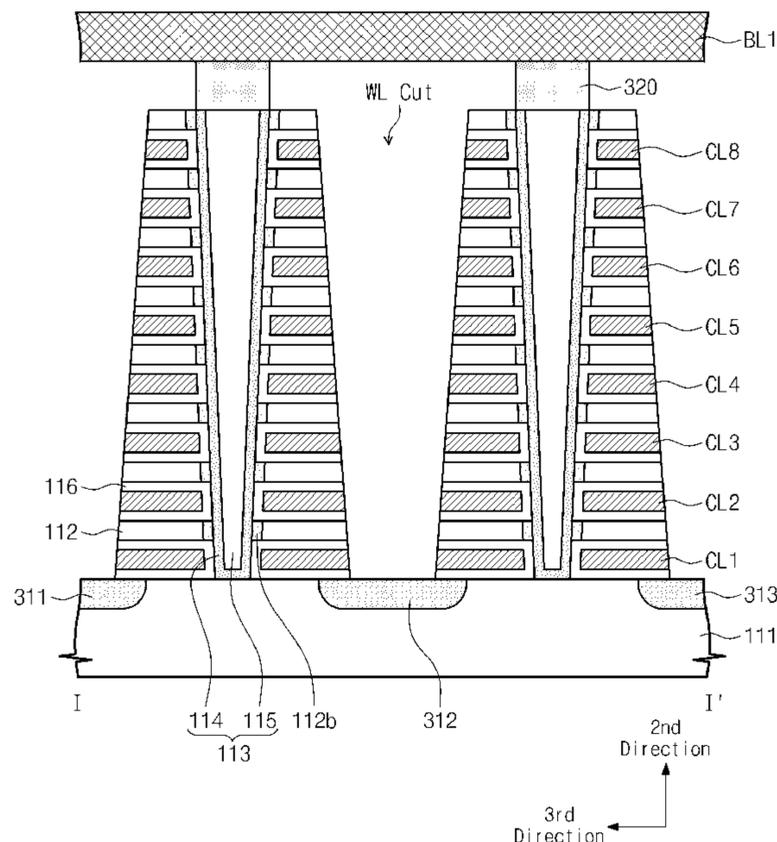


Fig. 1

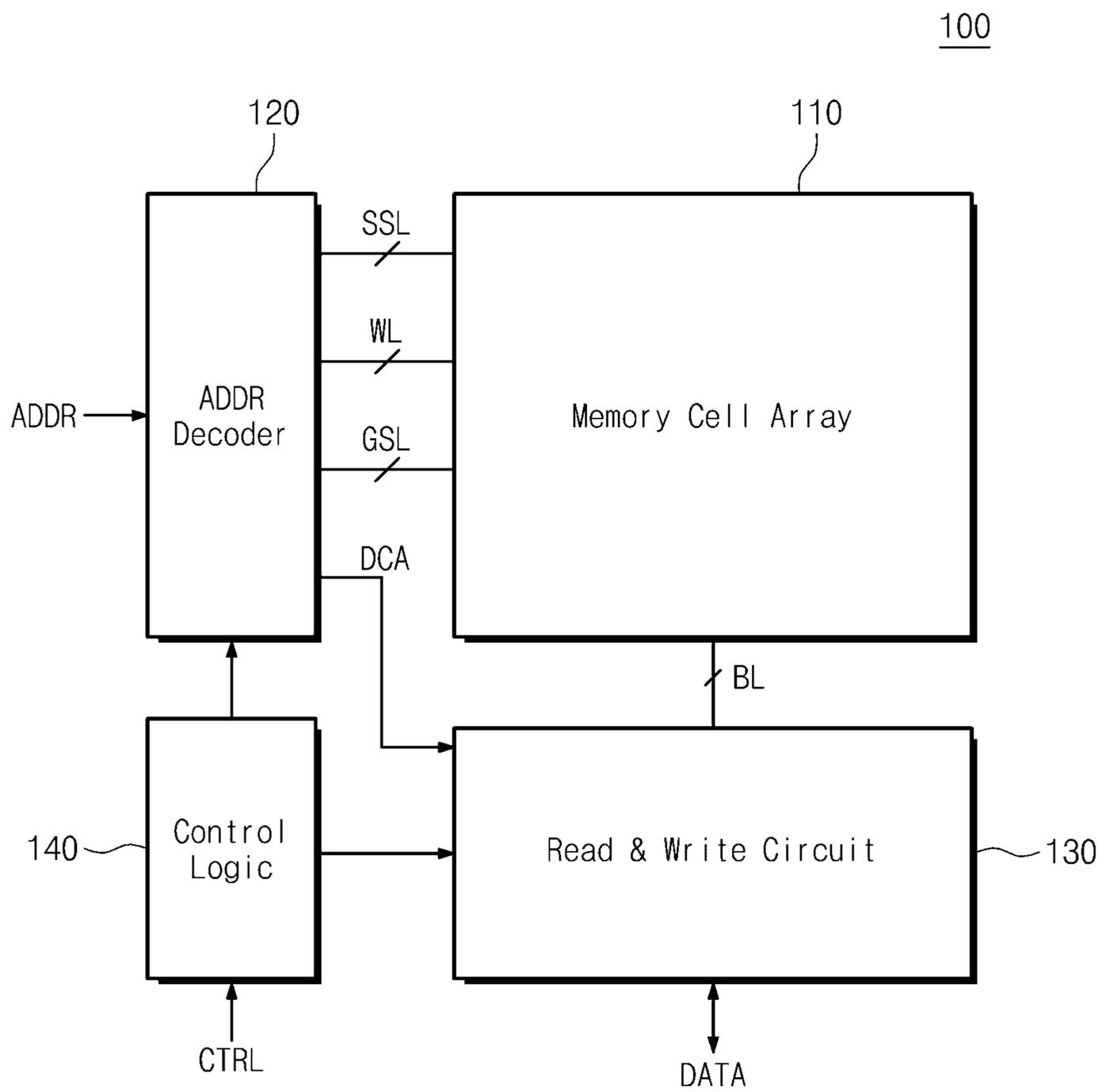


Fig. 2

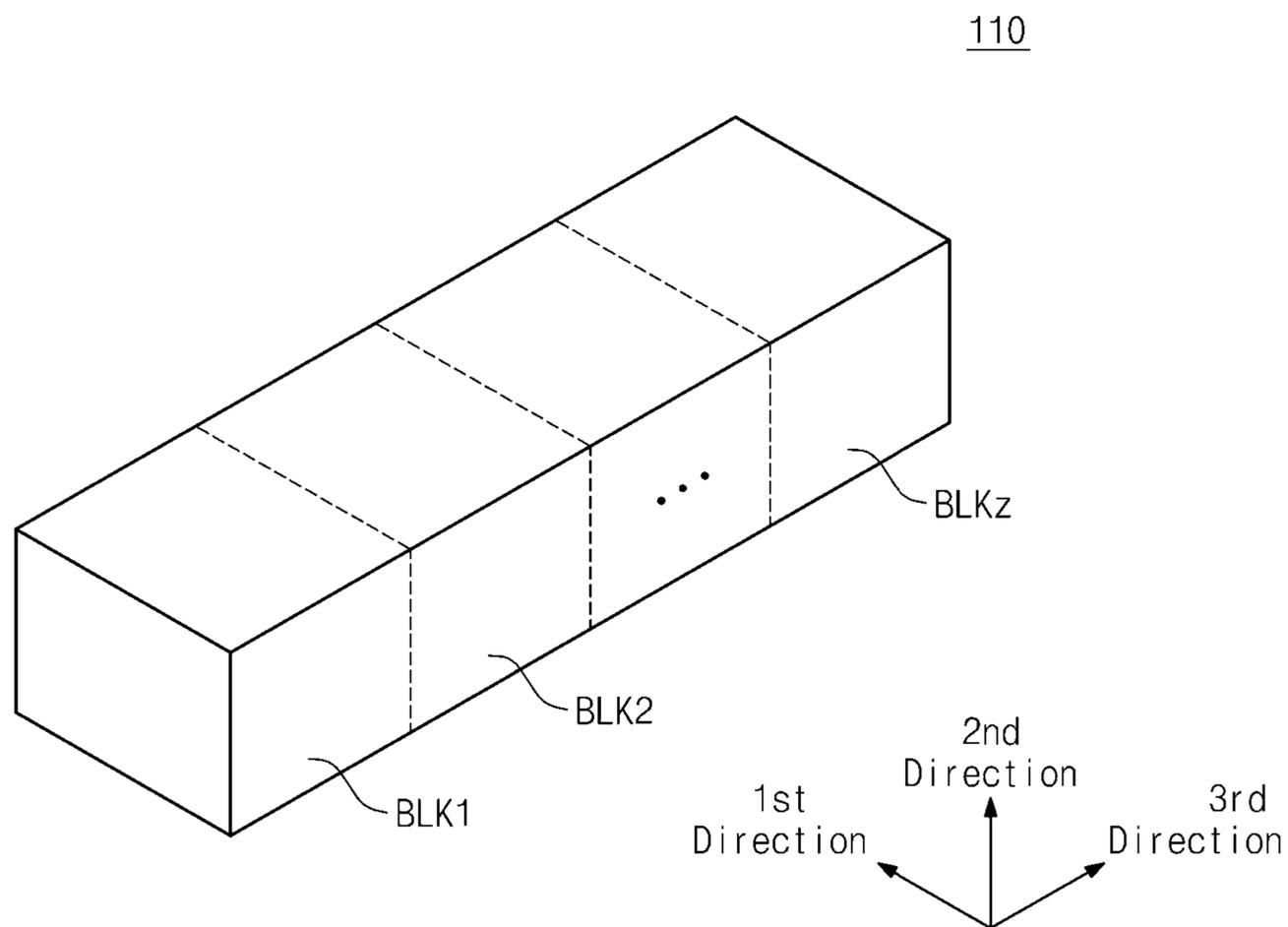


Fig. 3

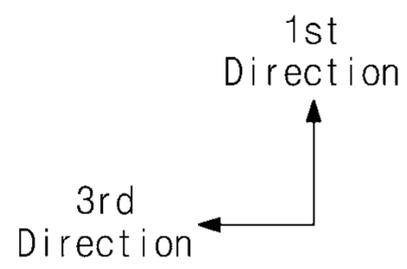
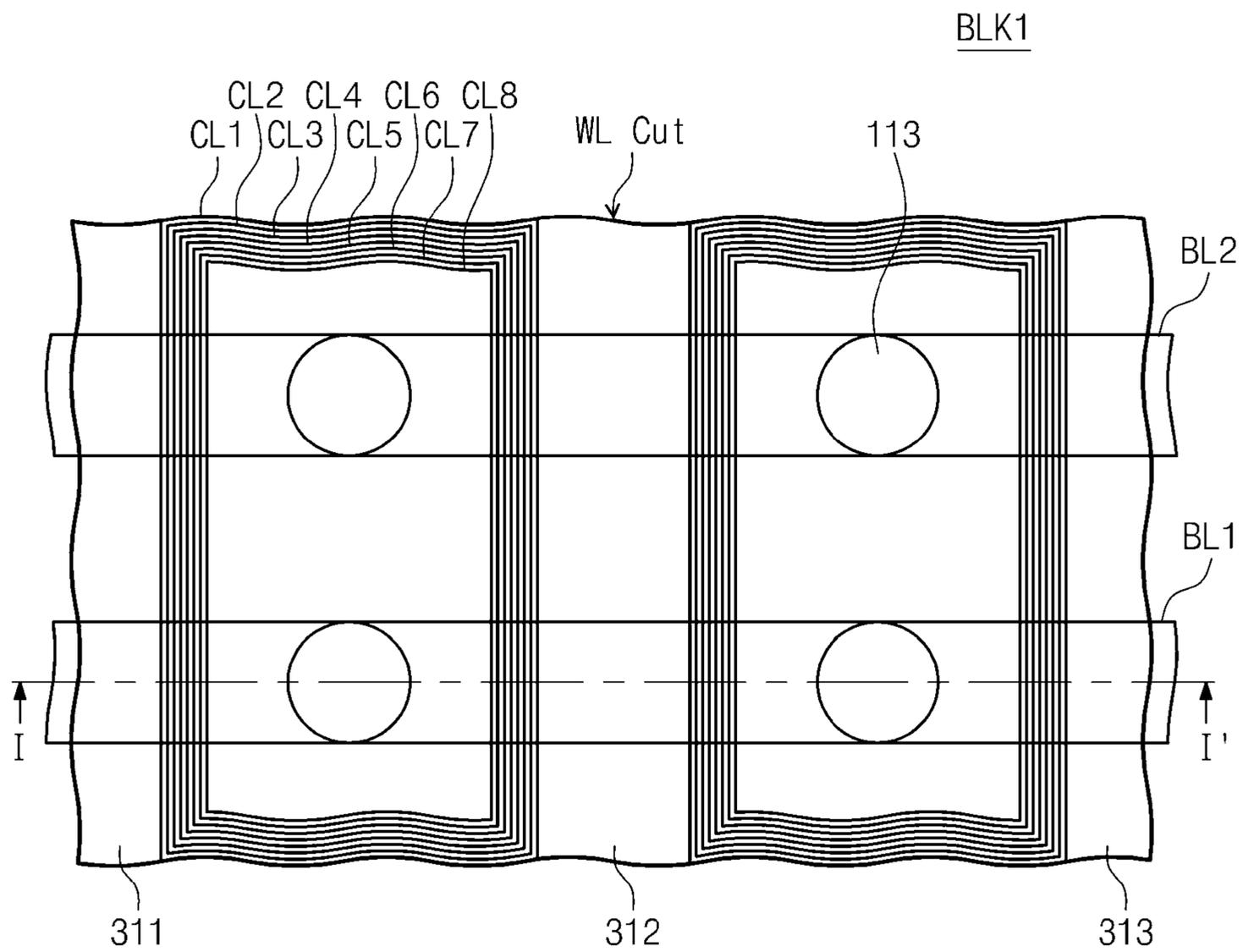


Fig. 4

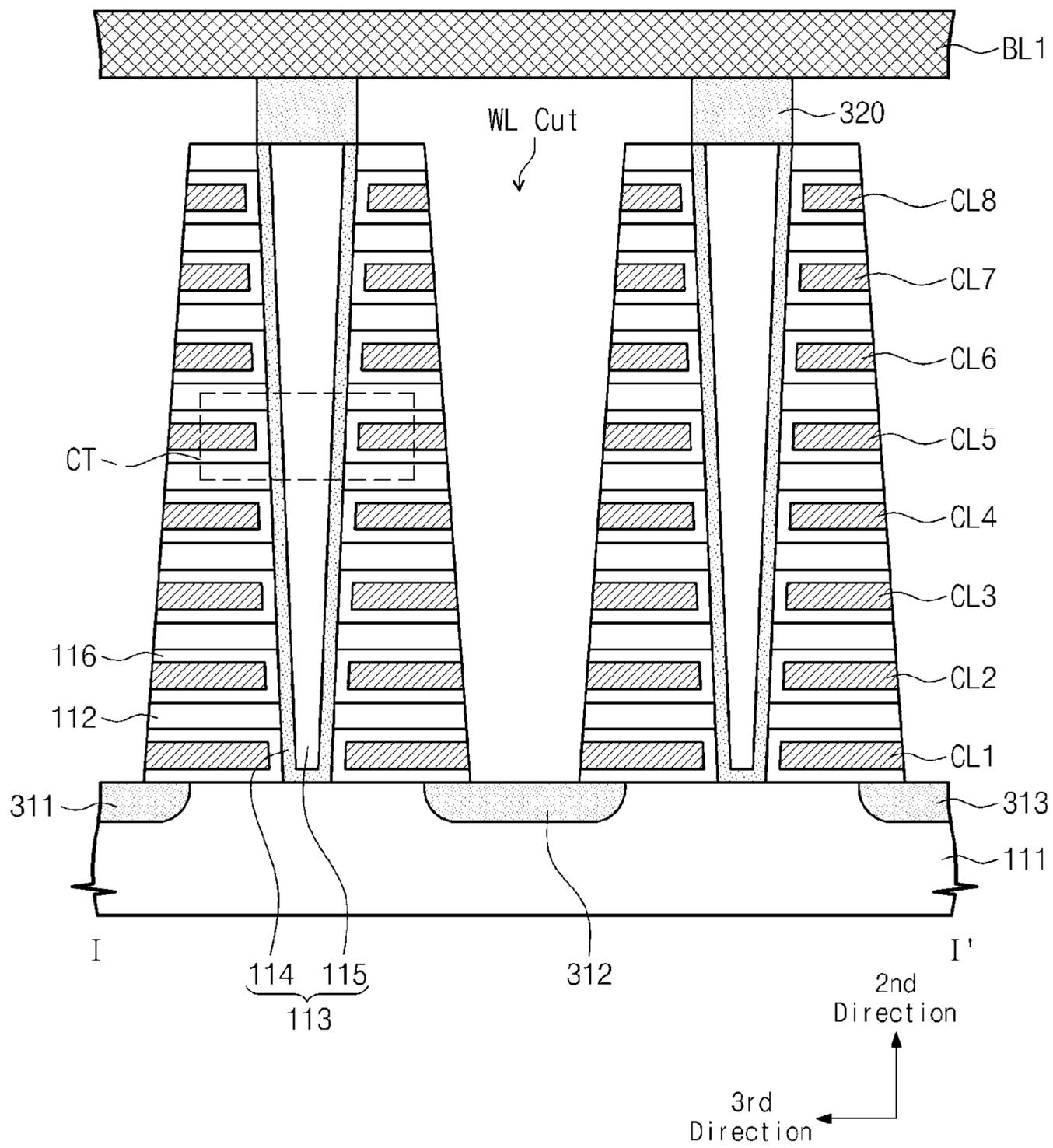


Fig. 5

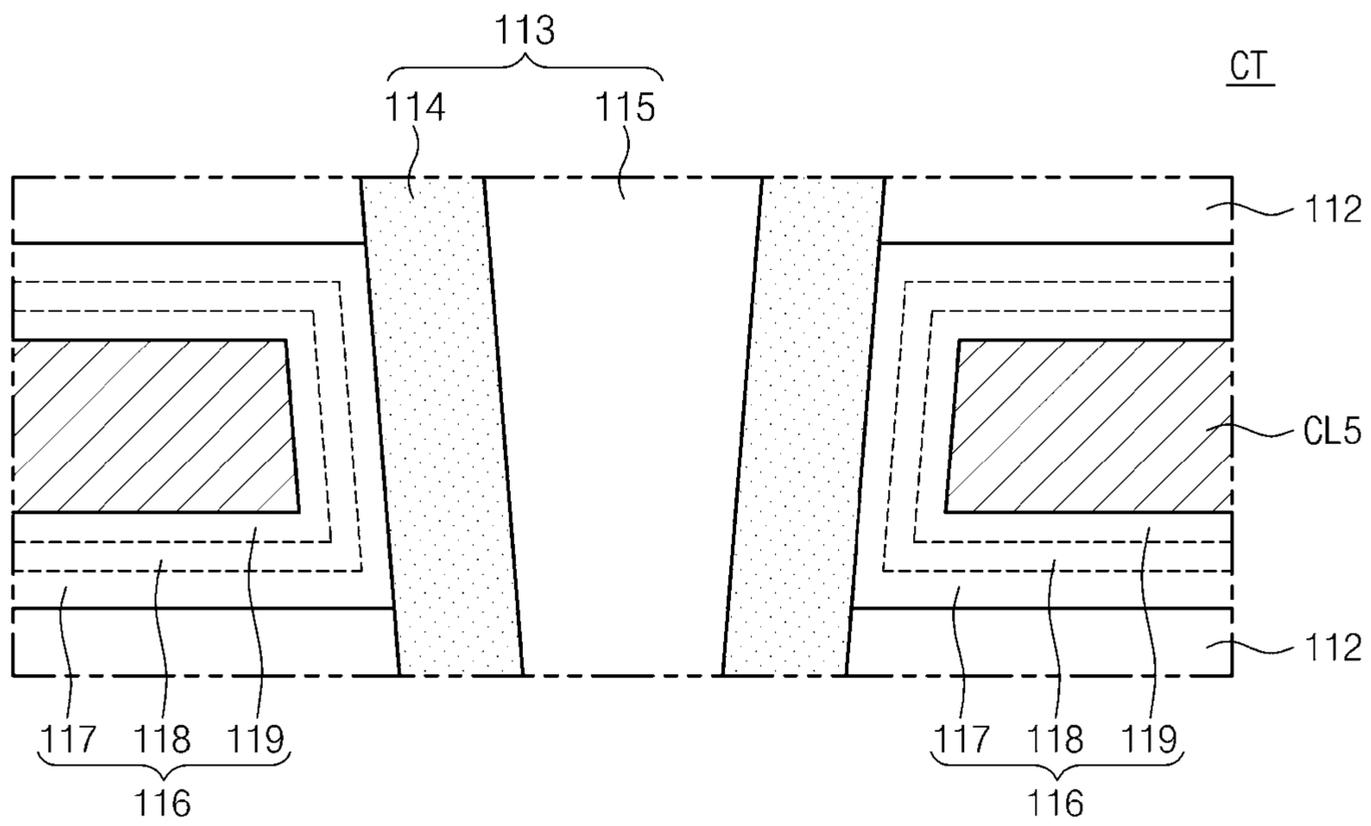


Fig. 6

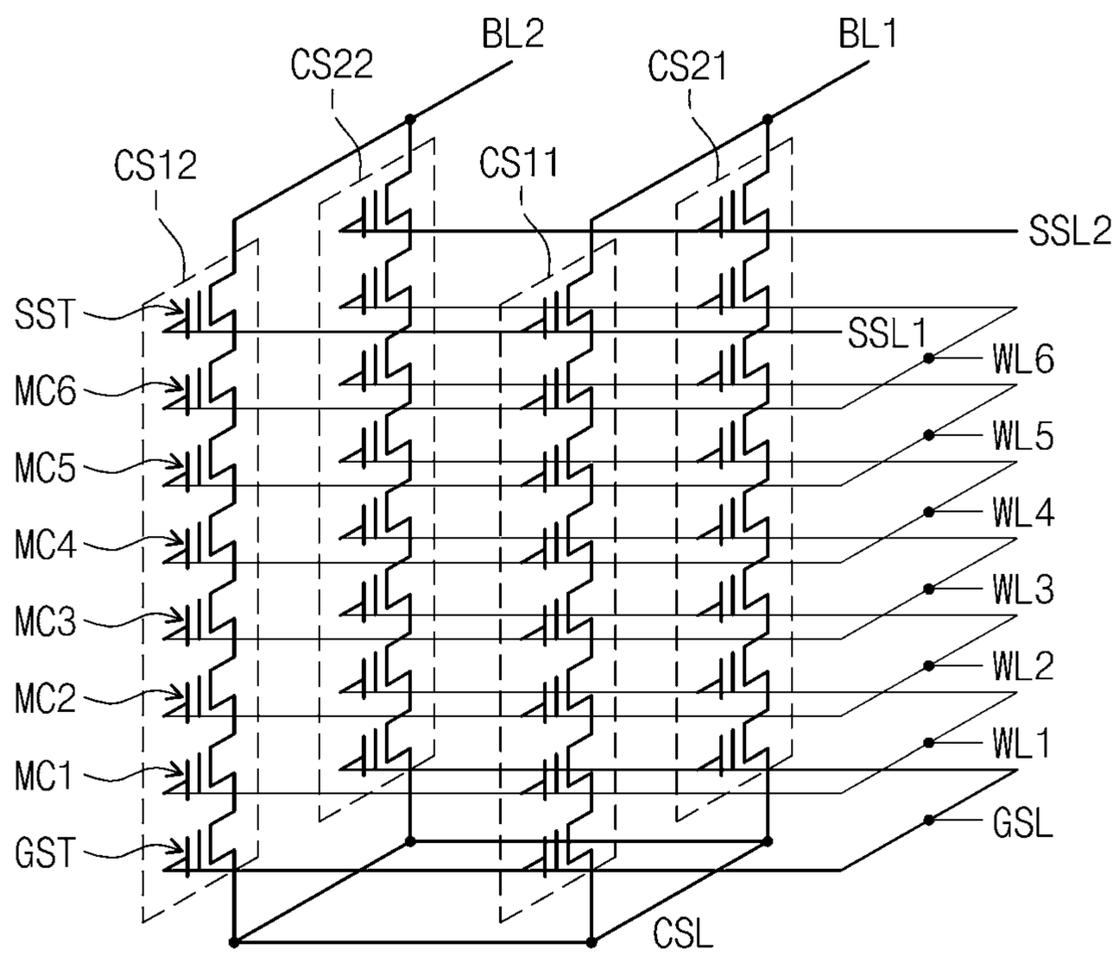


Fig. 7

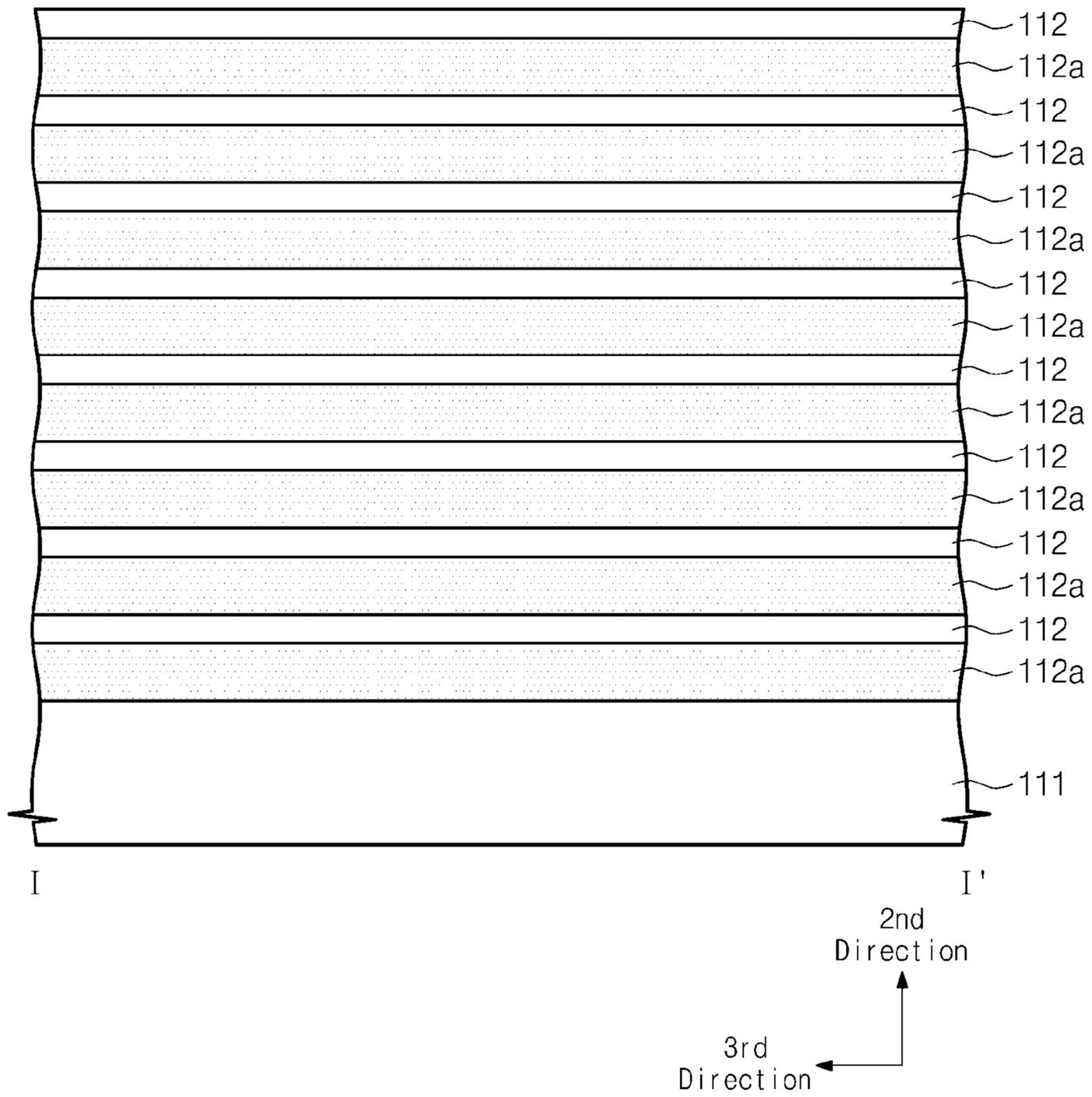


Fig. 8

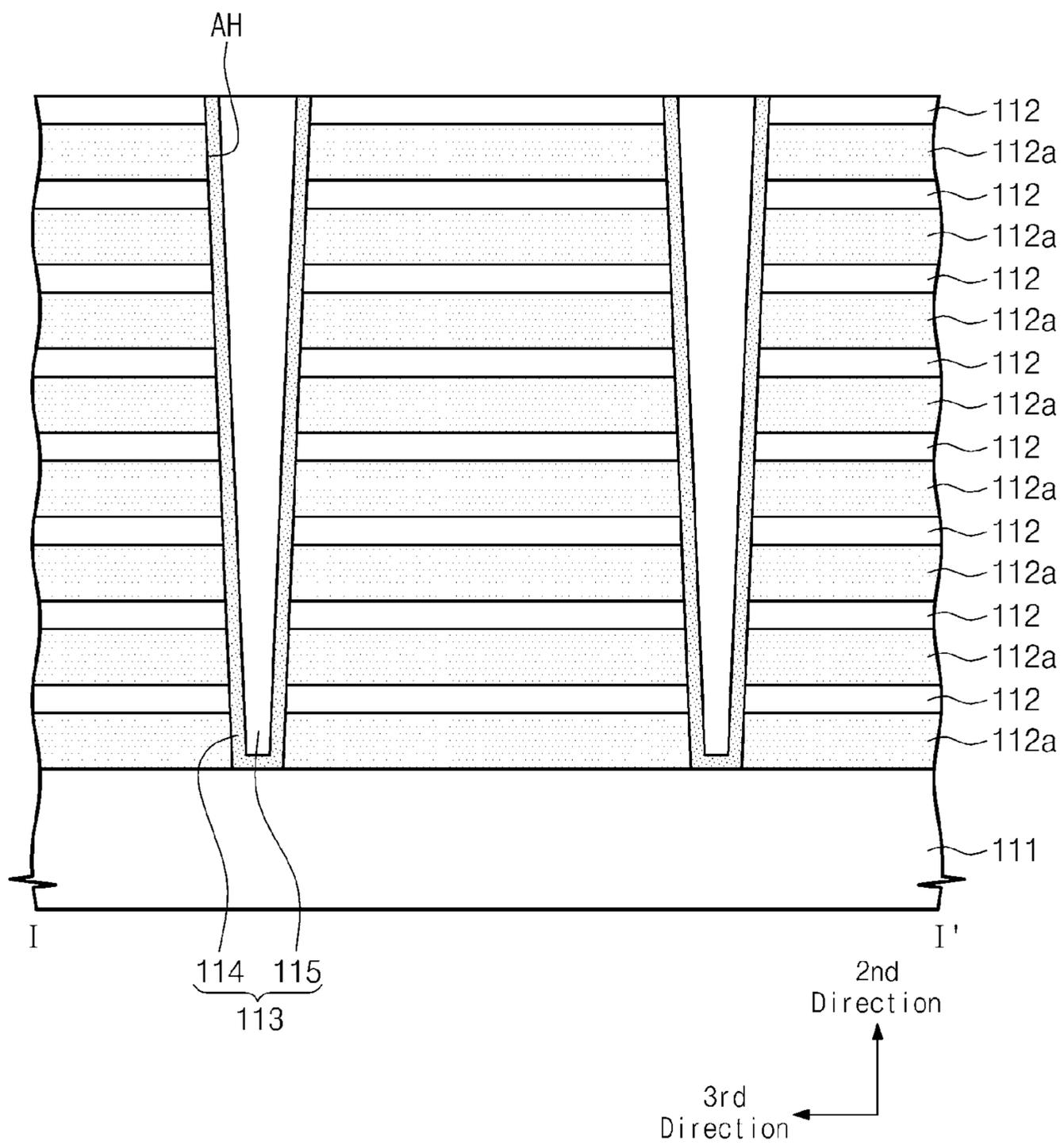


Fig. 9

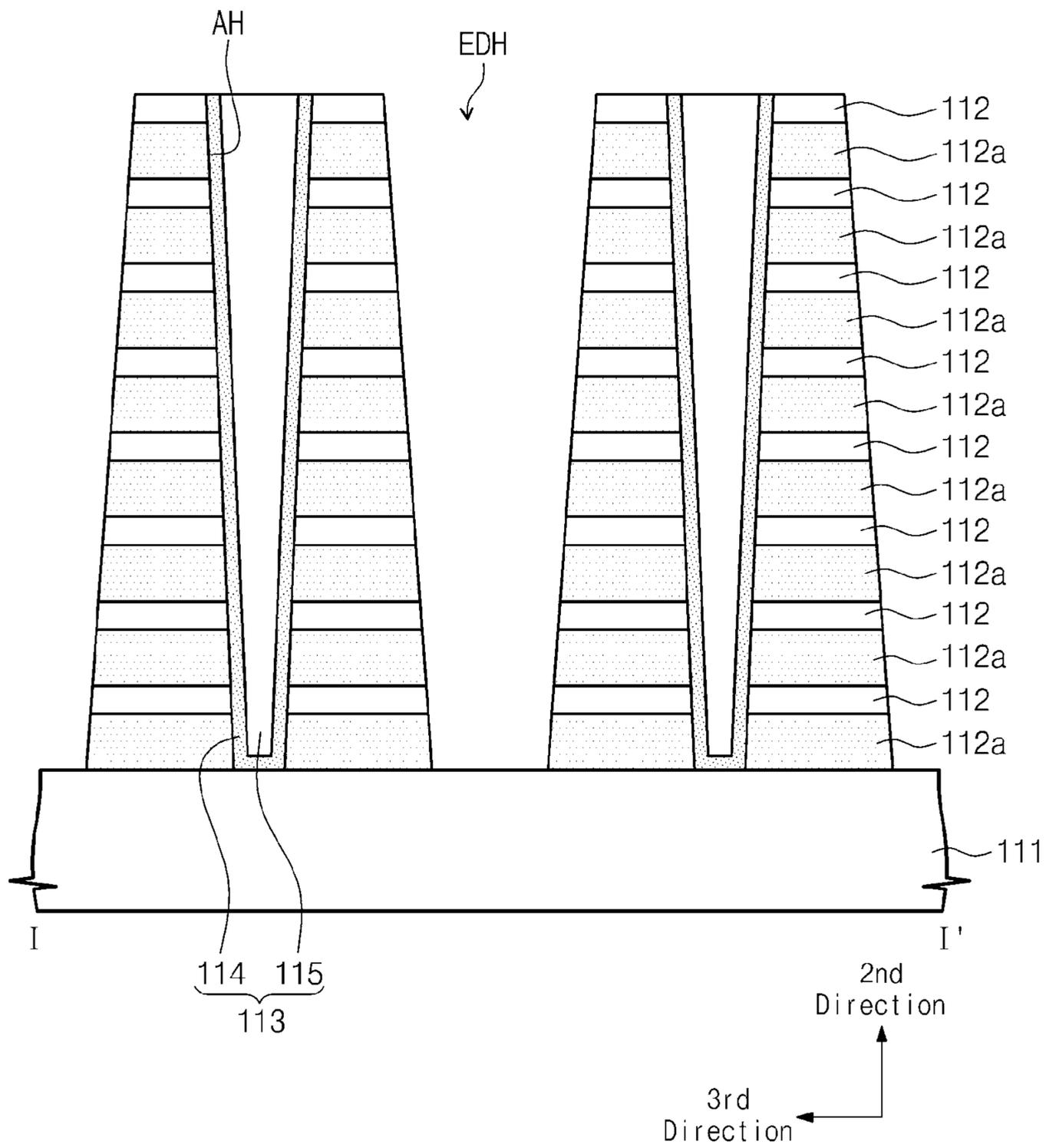


Fig. 10

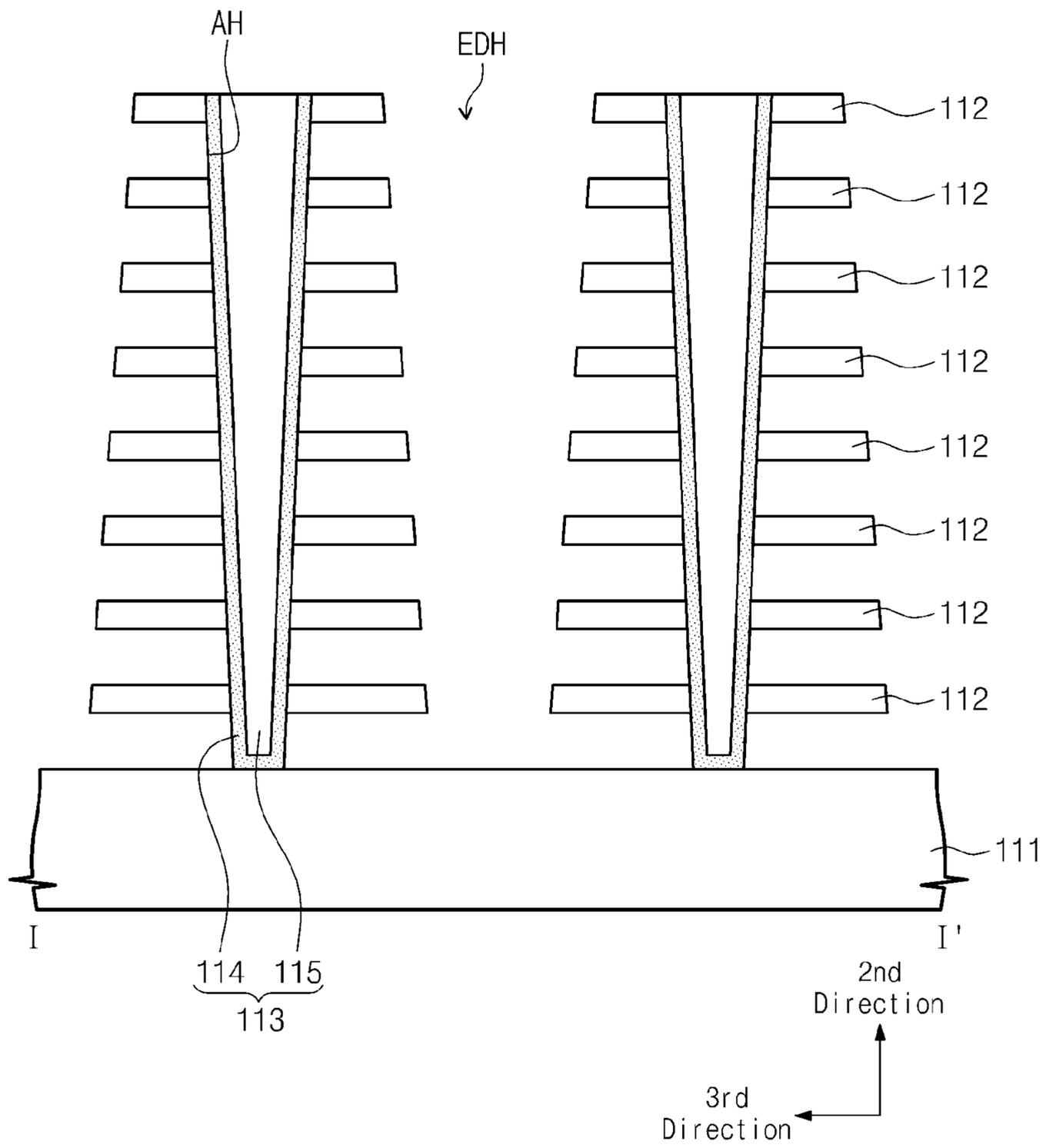


Fig. 11

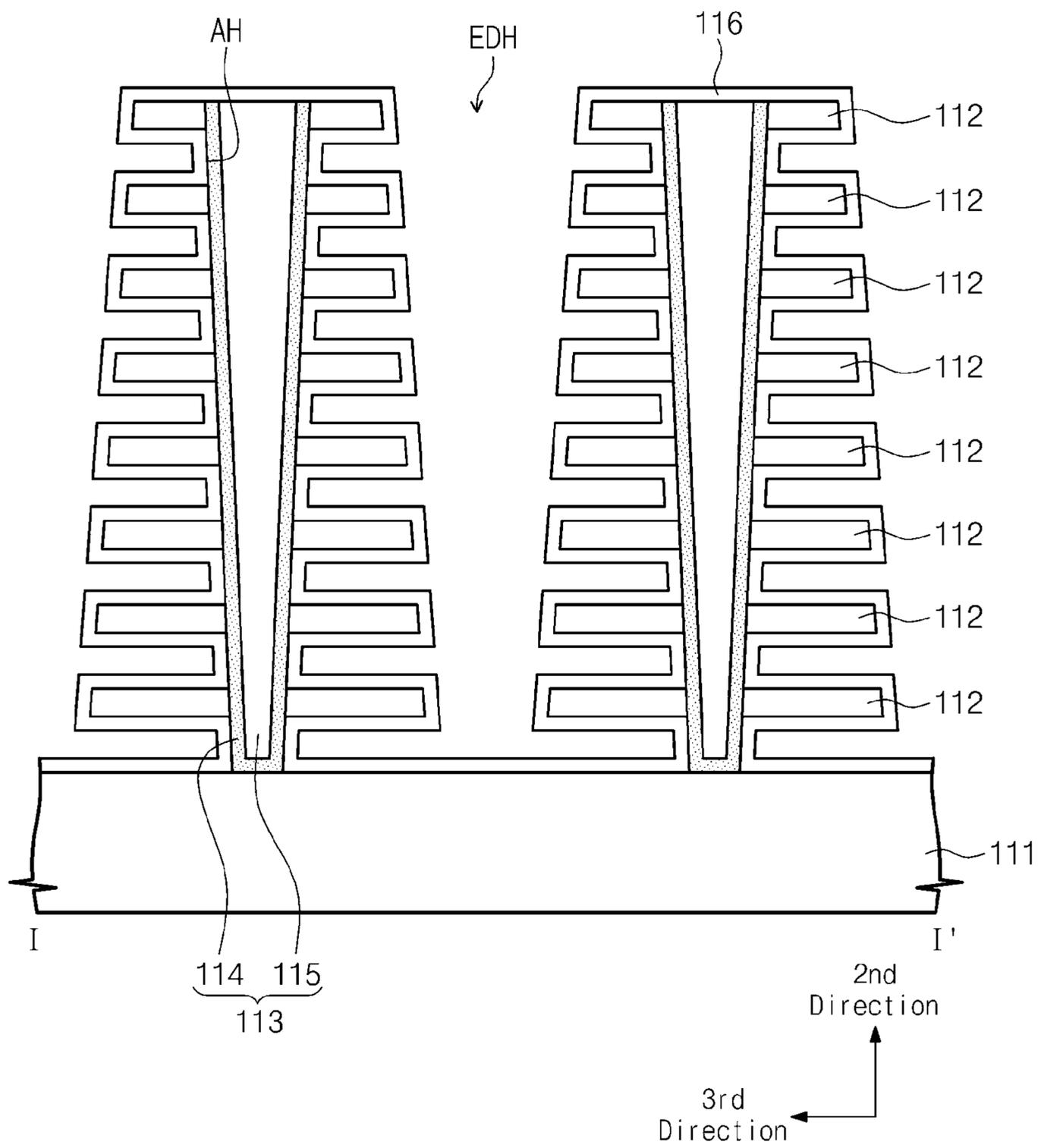


Fig. 12

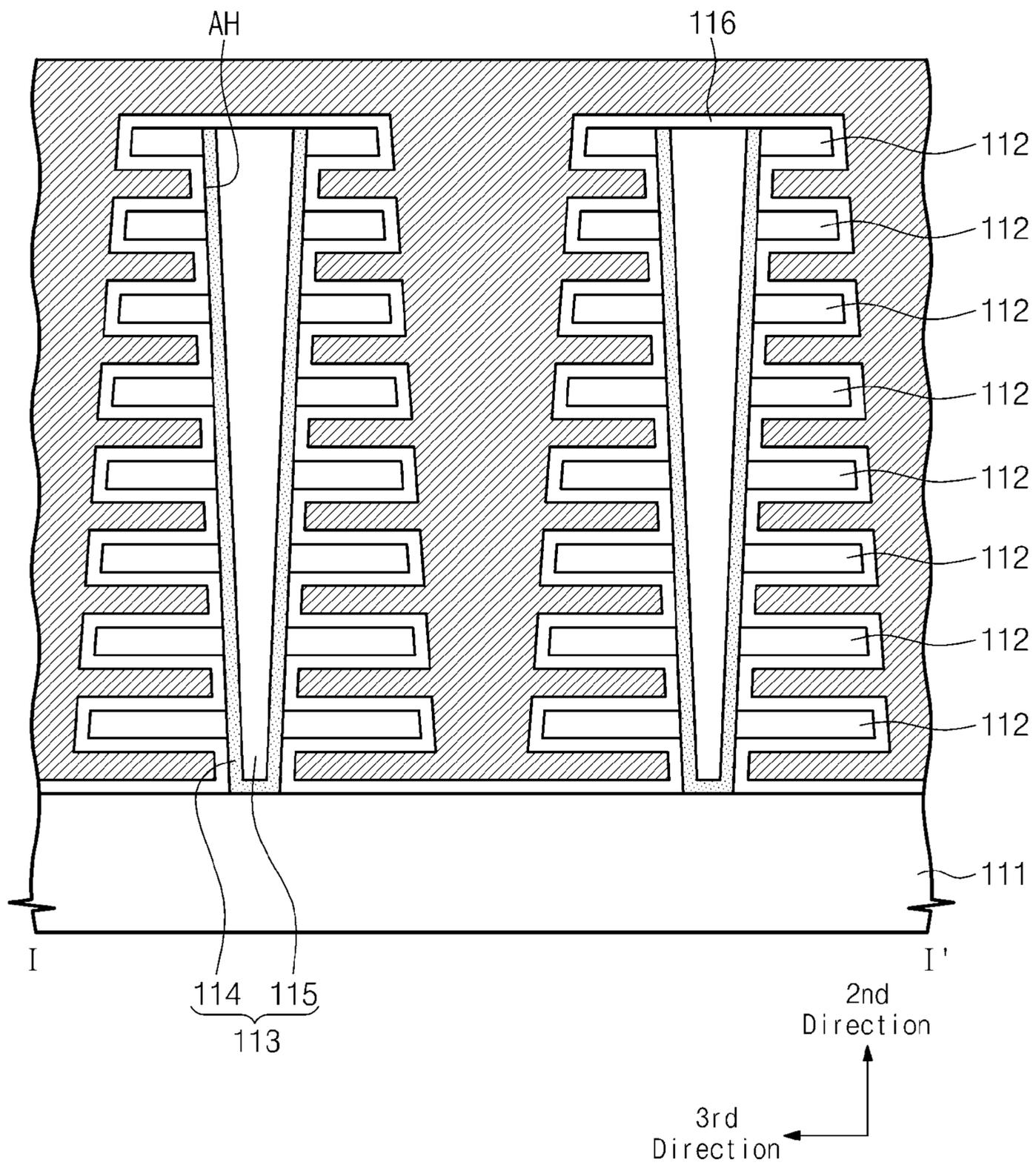


Fig. 13

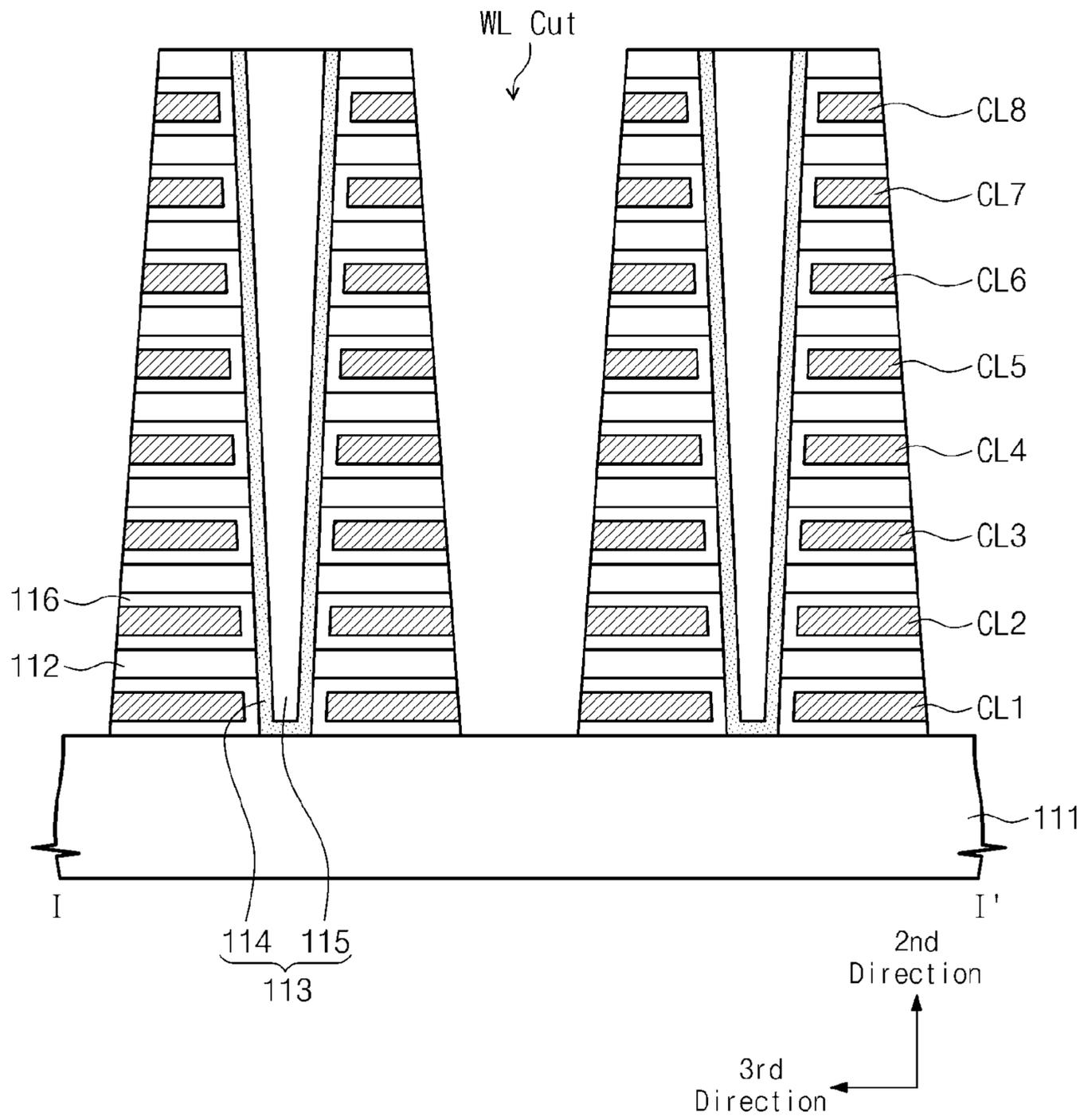


Fig. 14

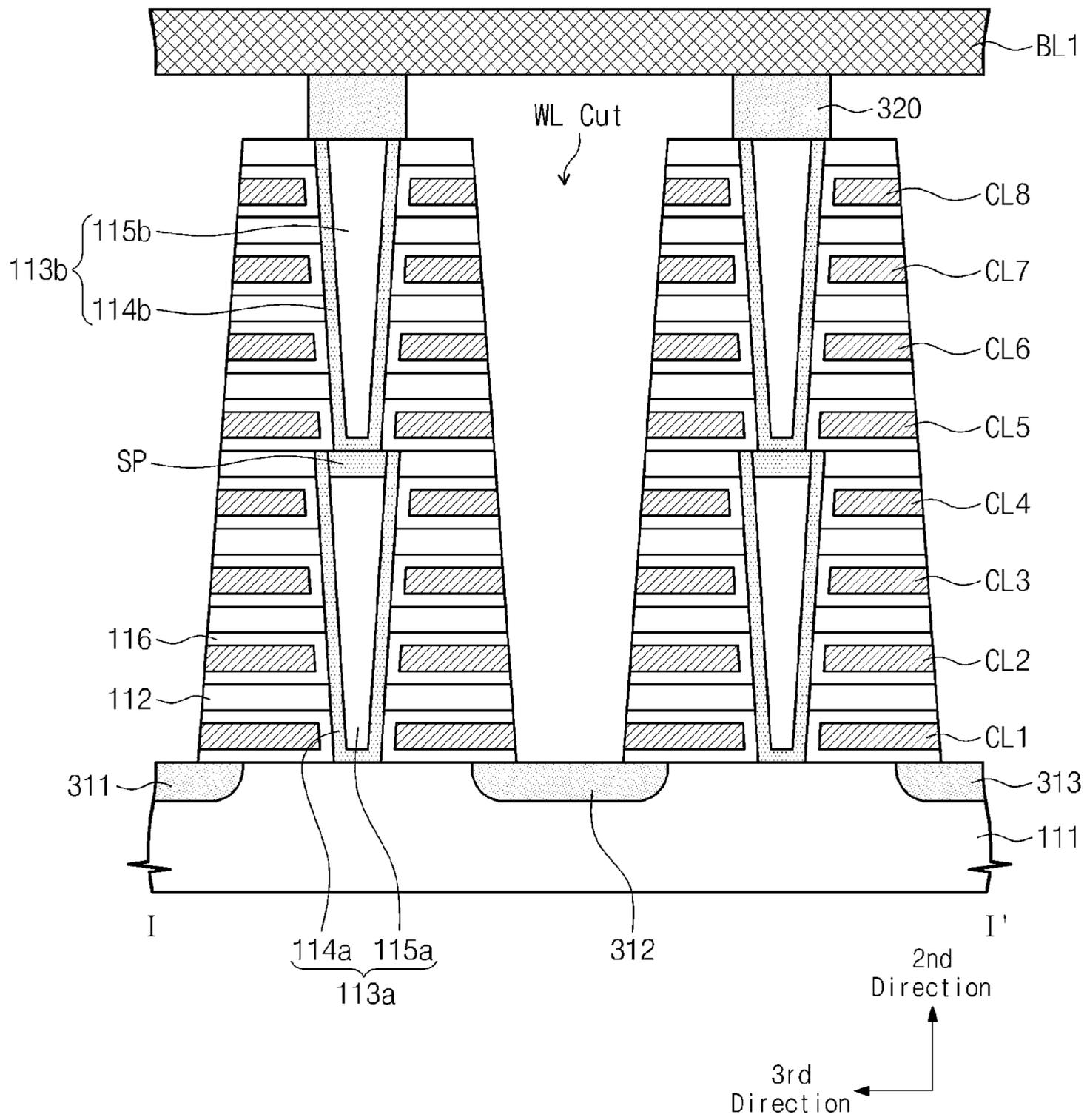


Fig. 15

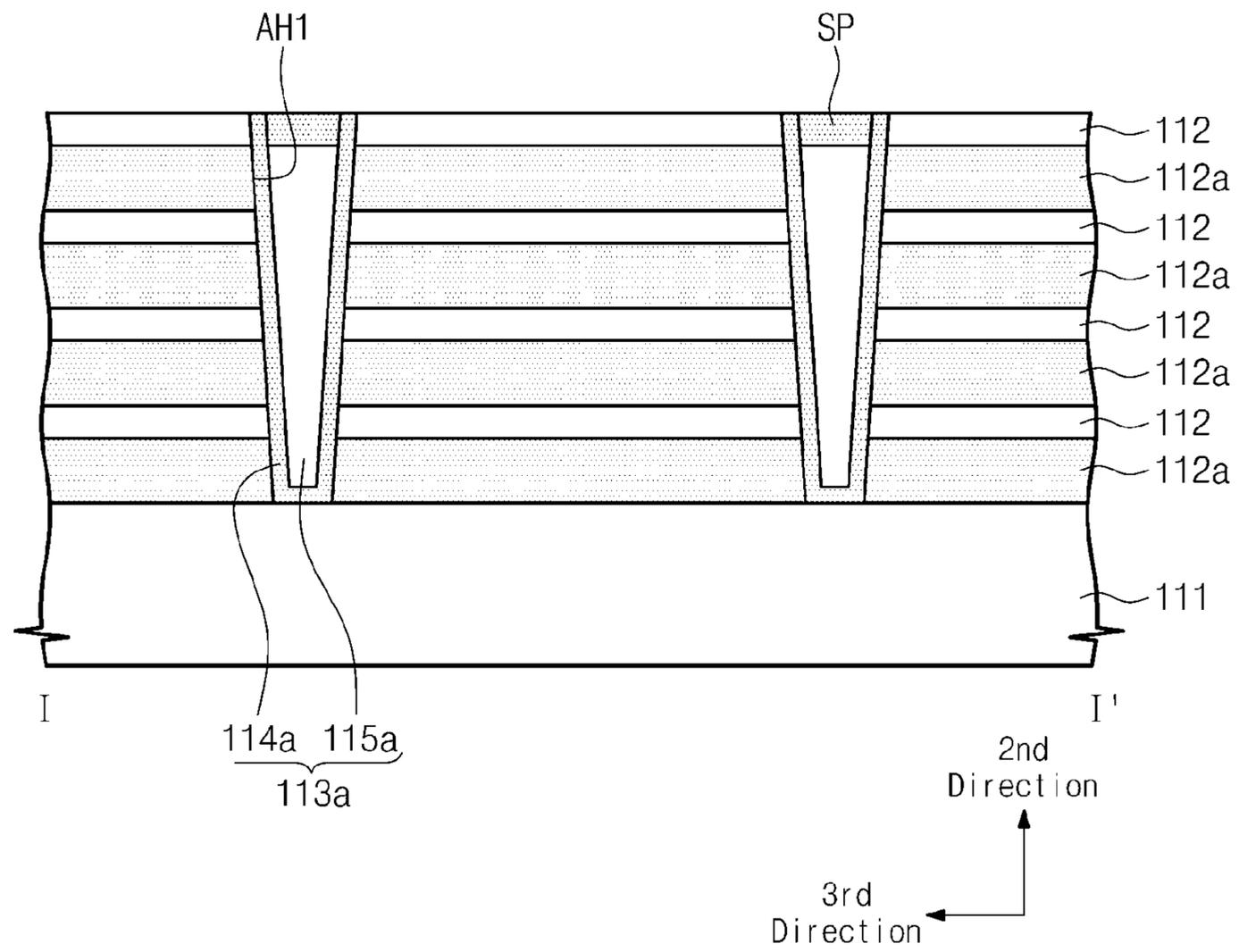


Fig. 16

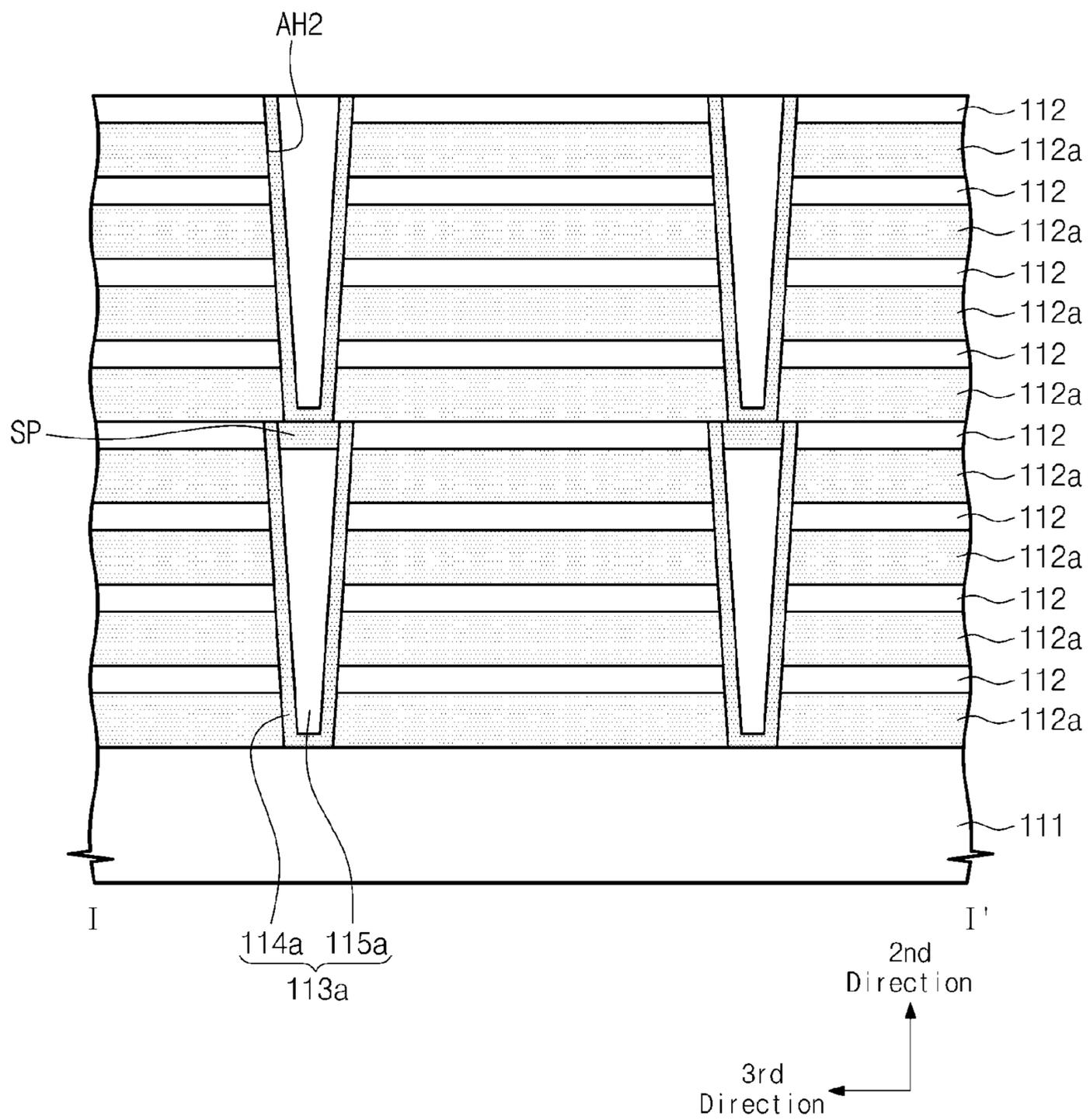


Fig. 17

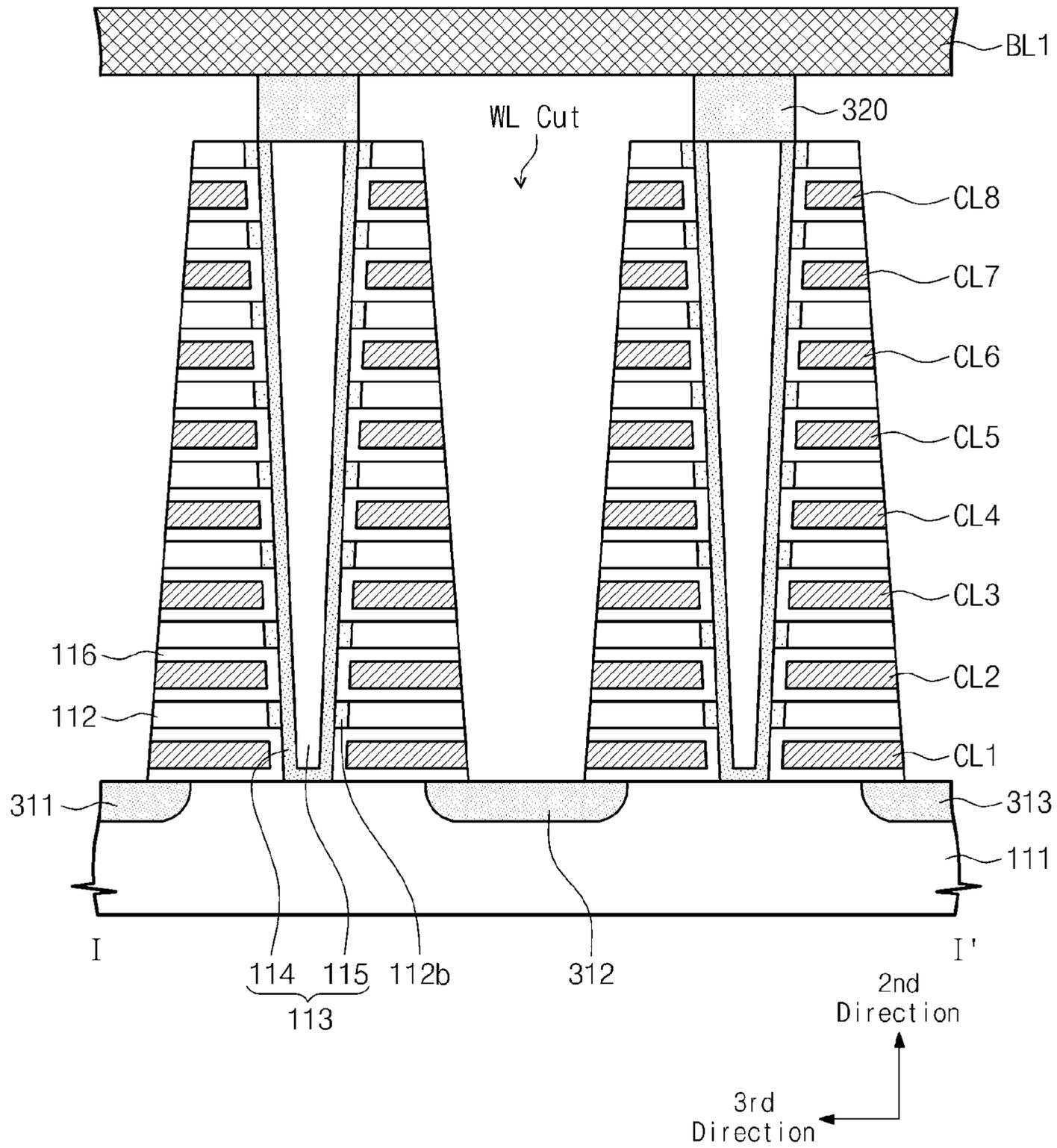


Fig. 18

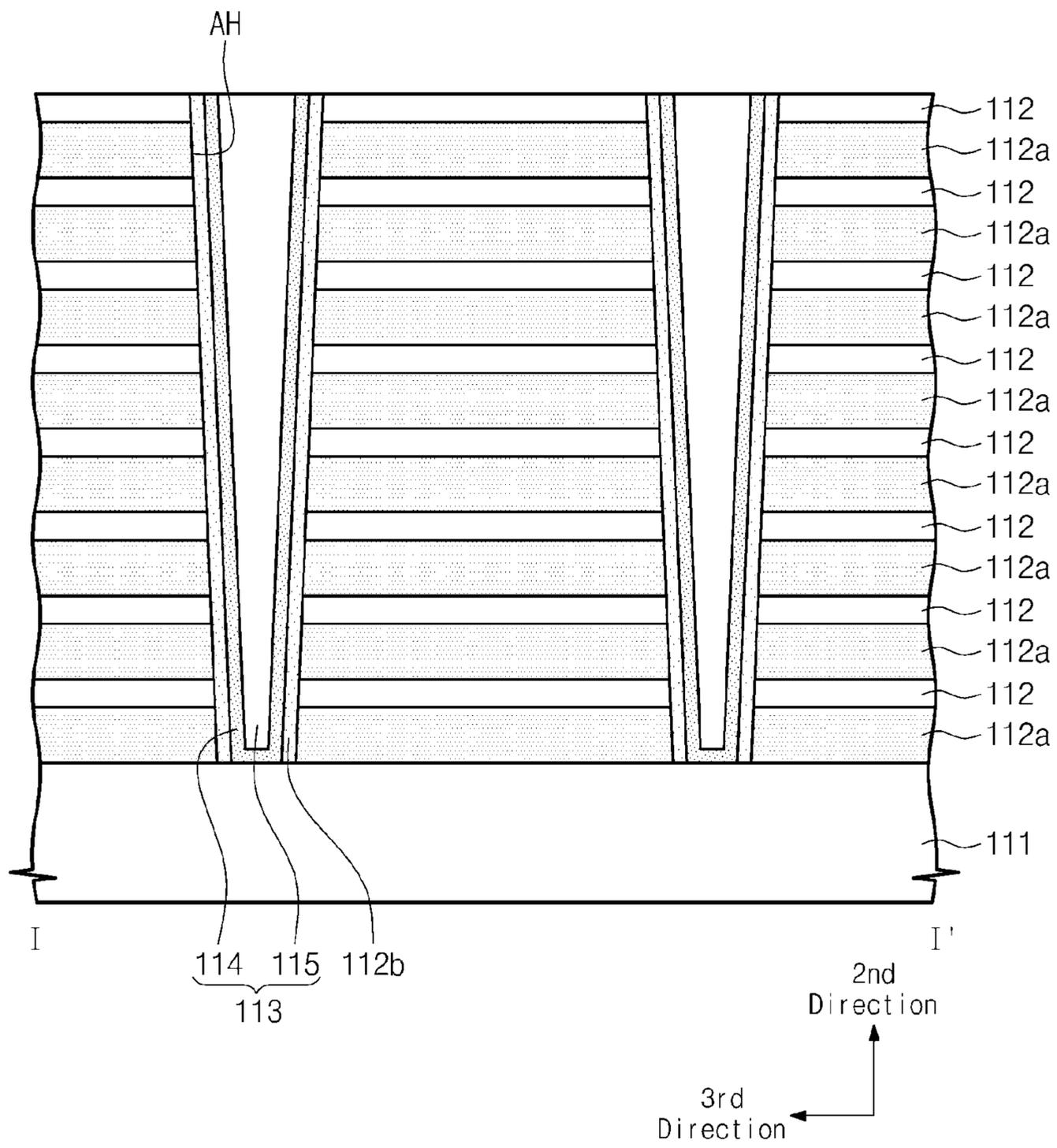


Fig. 19

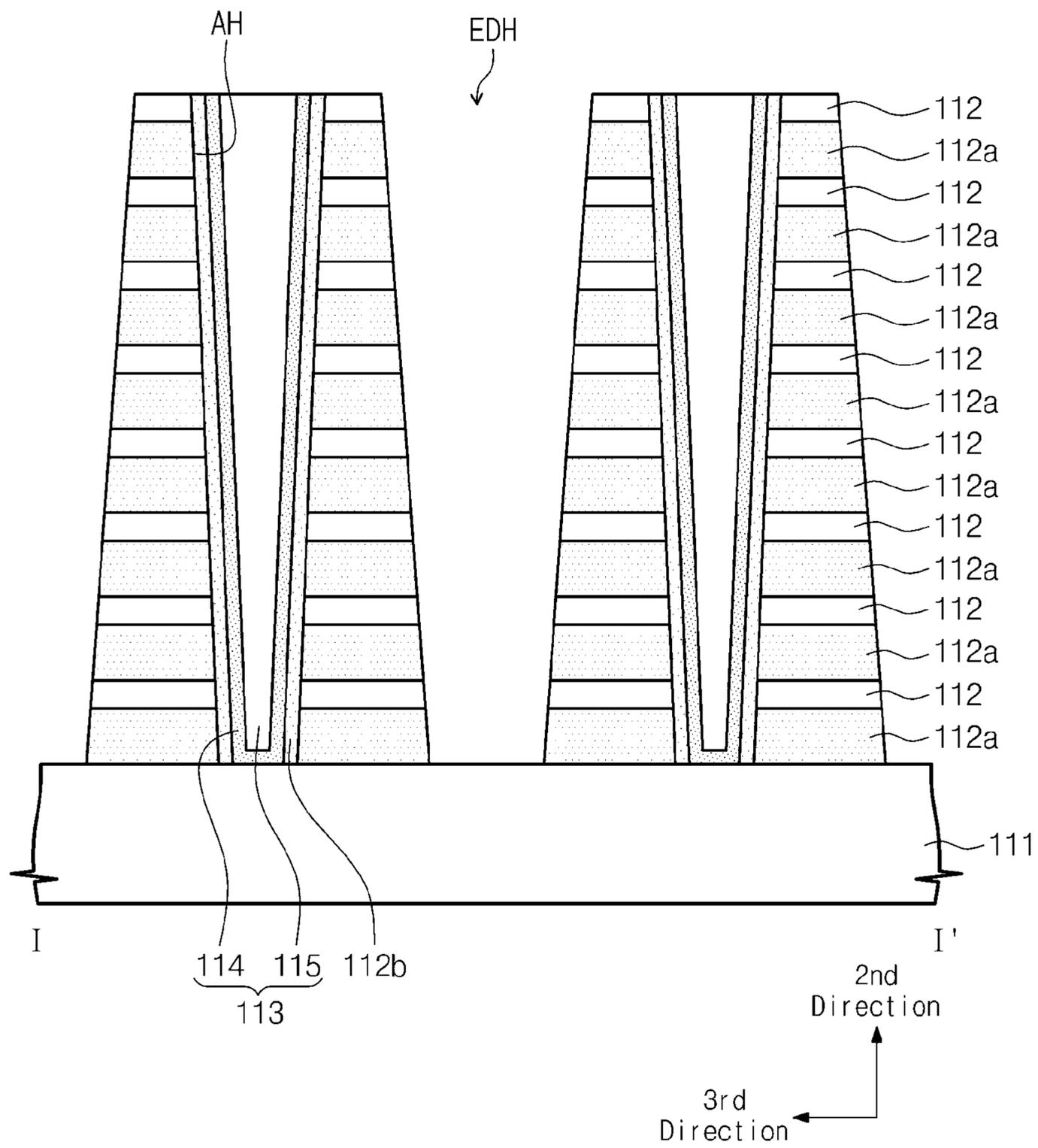


Fig. 20

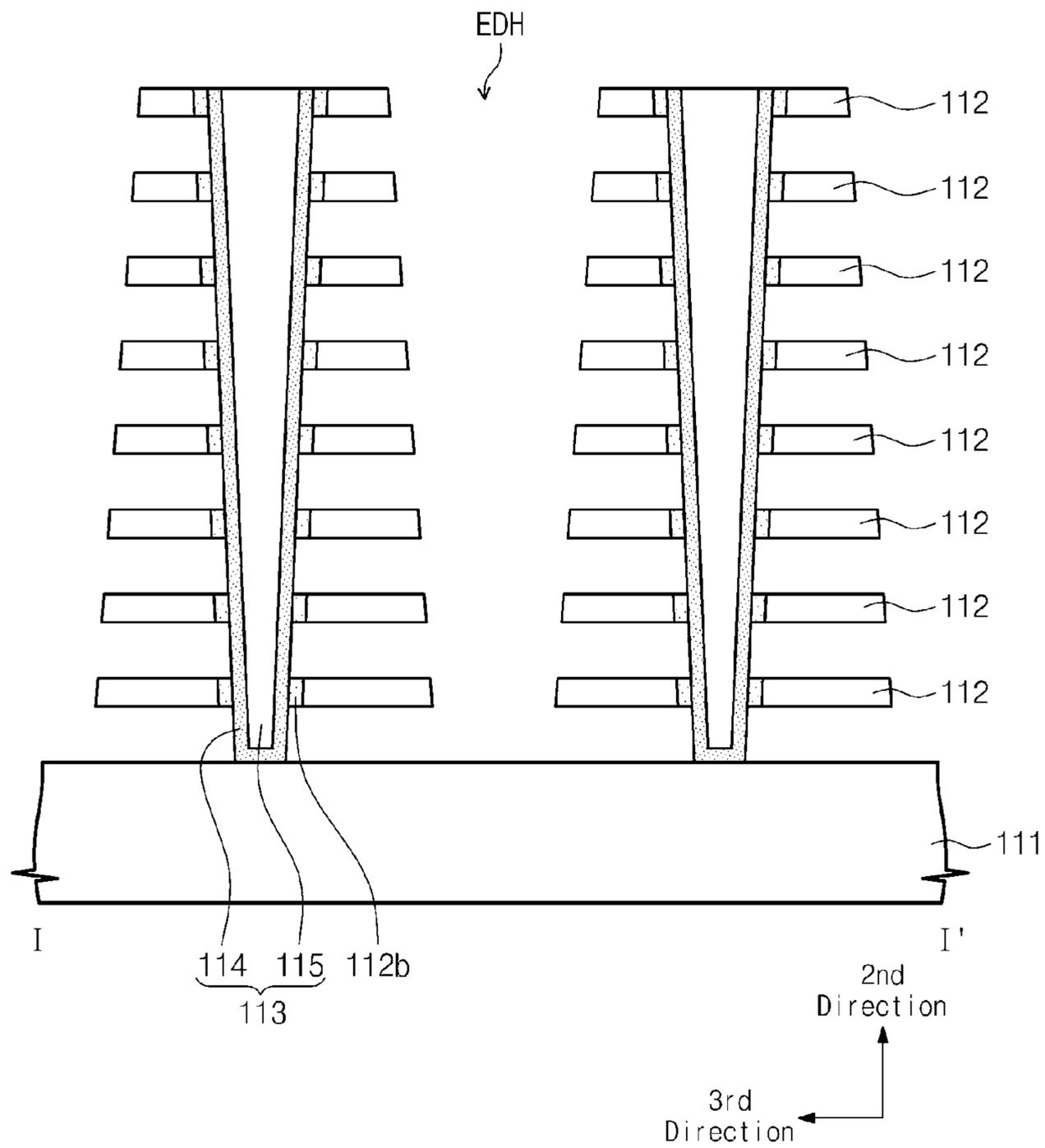


Fig. 22

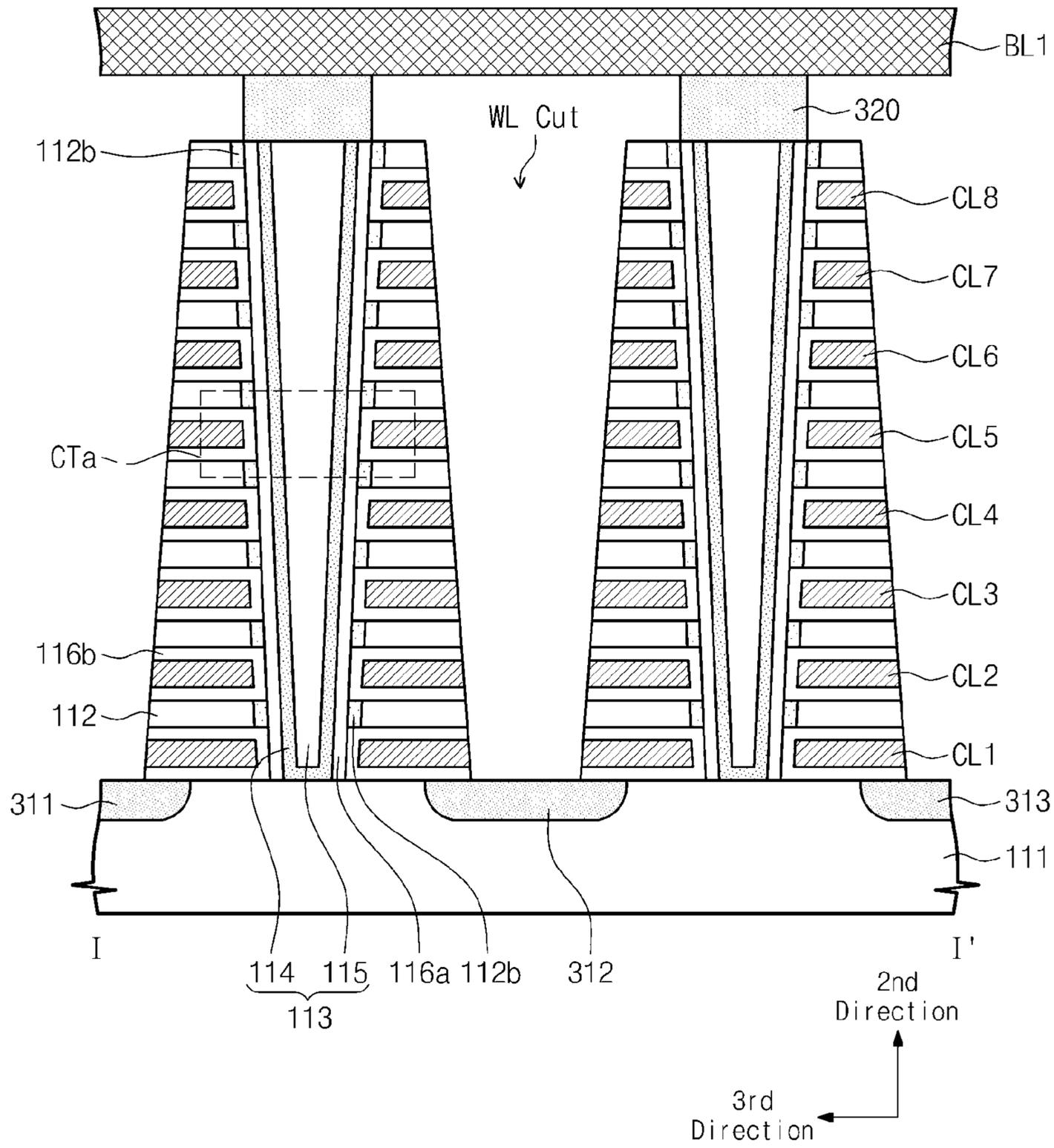


Fig. 23

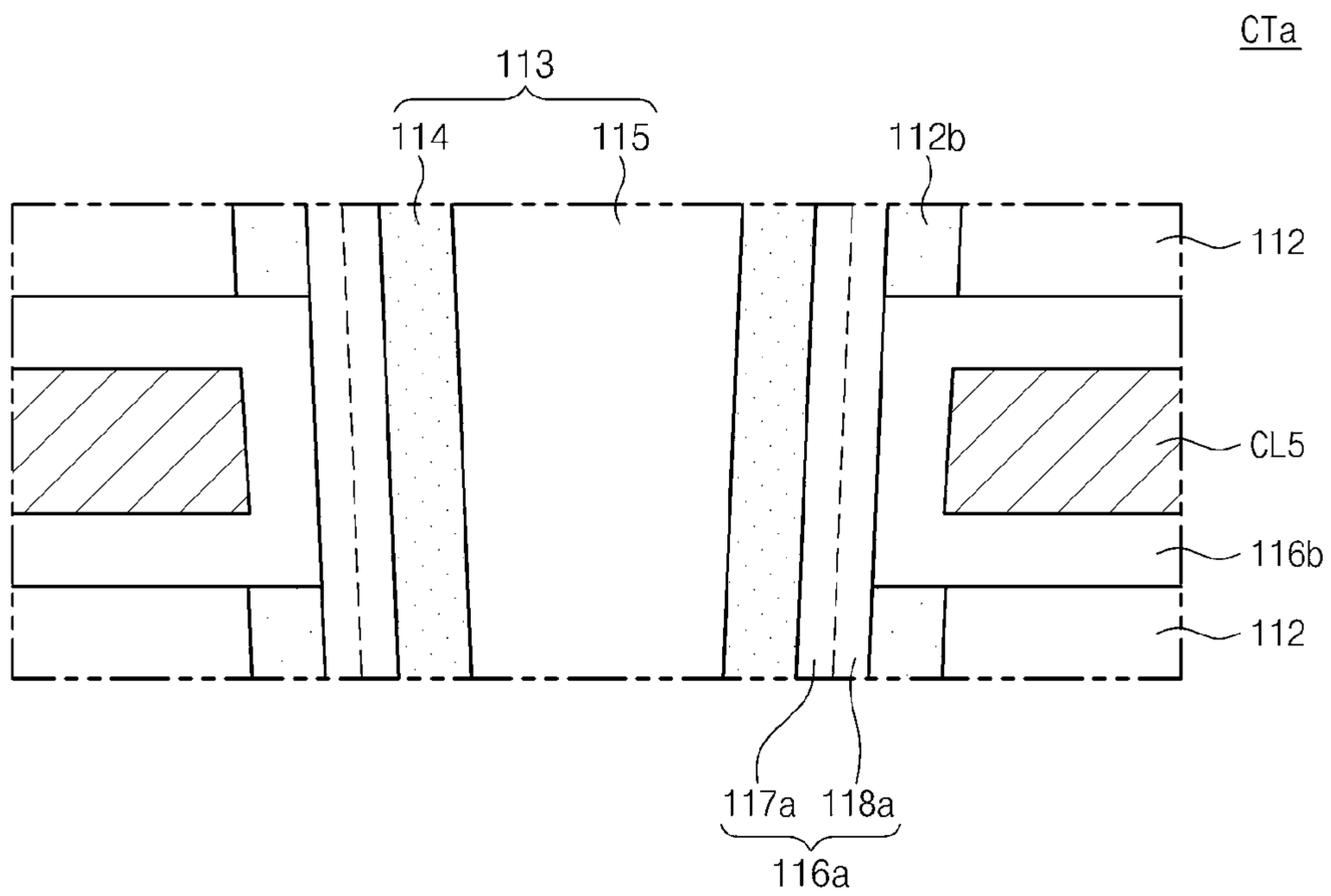


Fig. 24

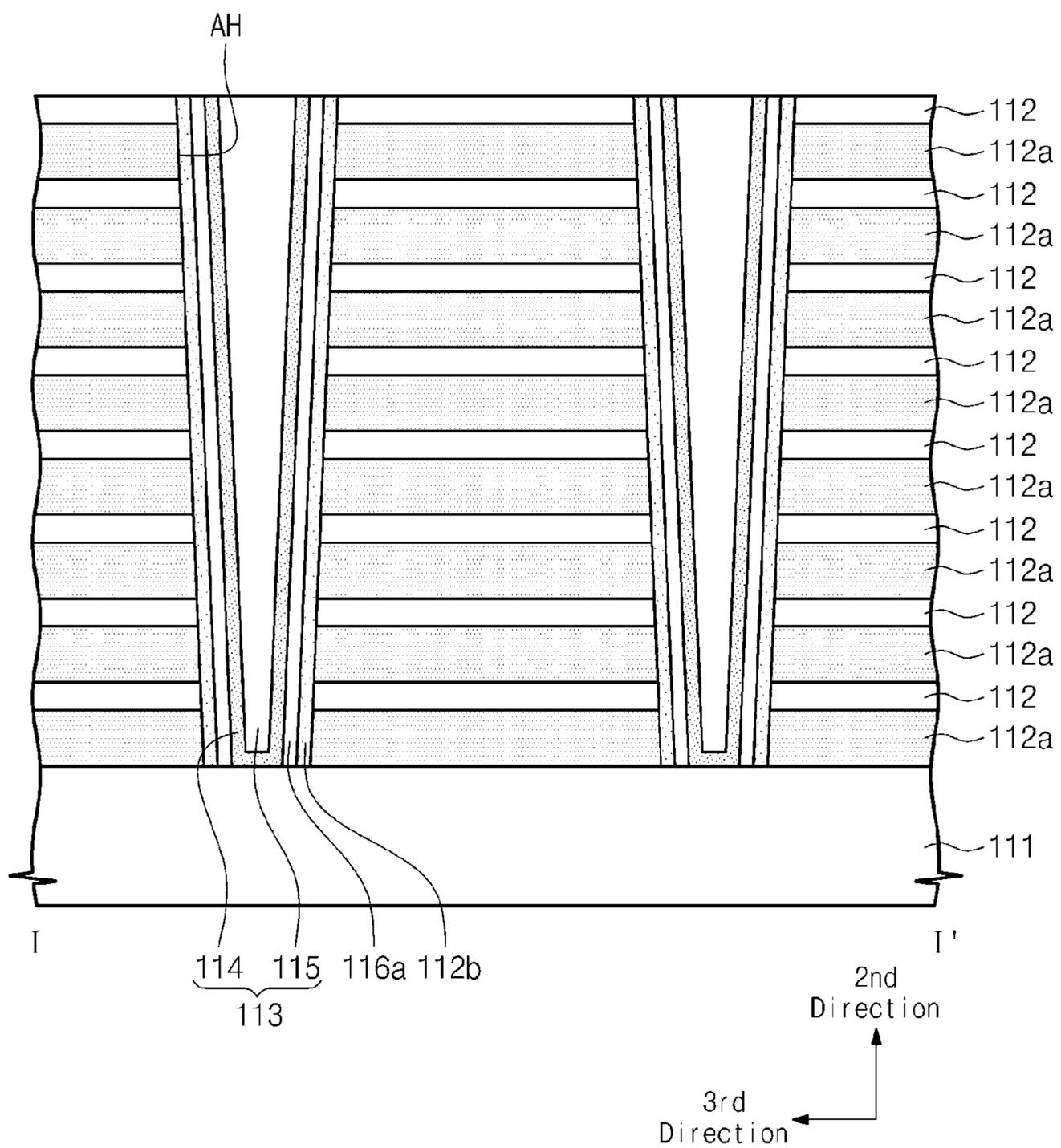


Fig. 25

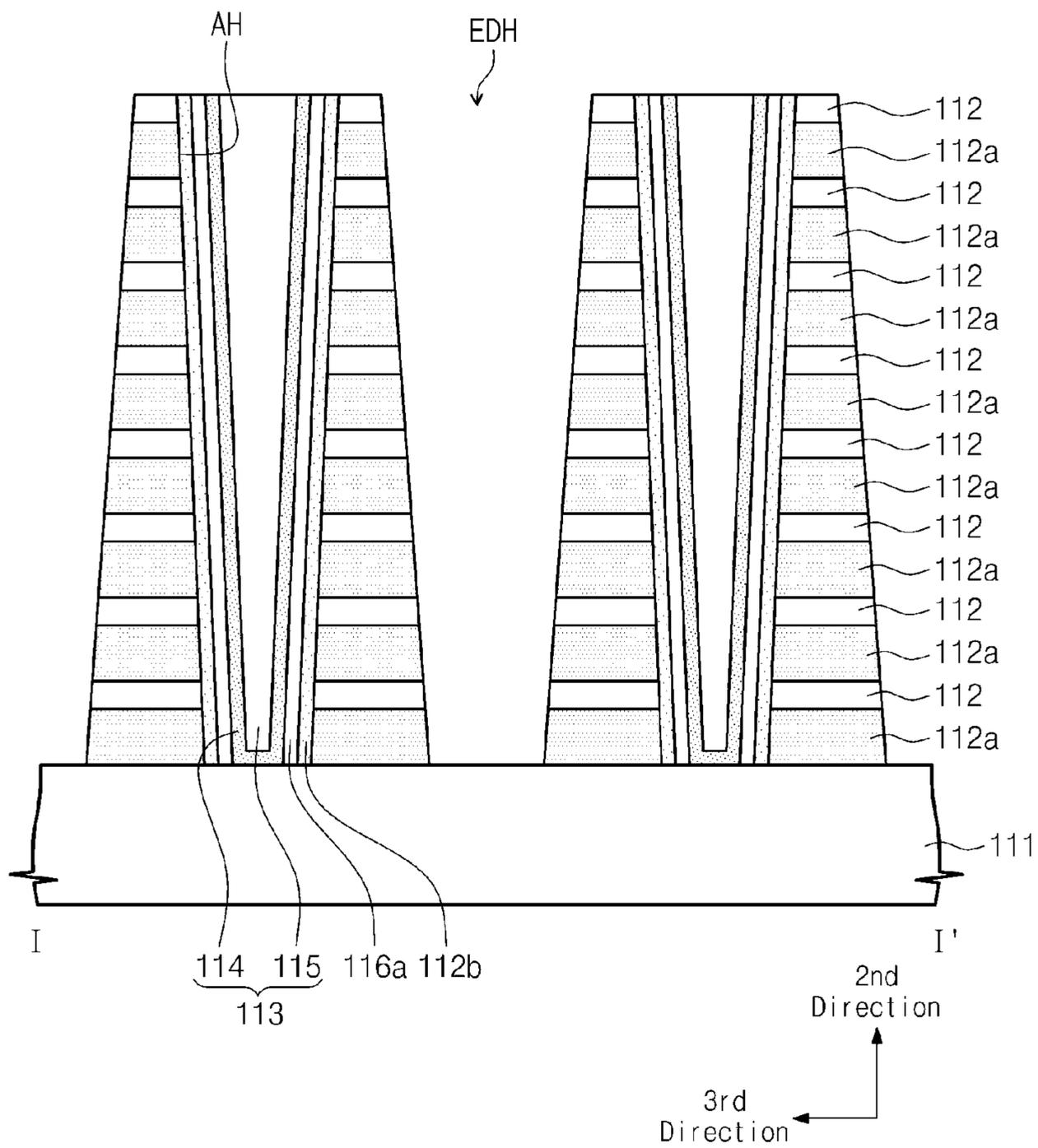


Fig. 26

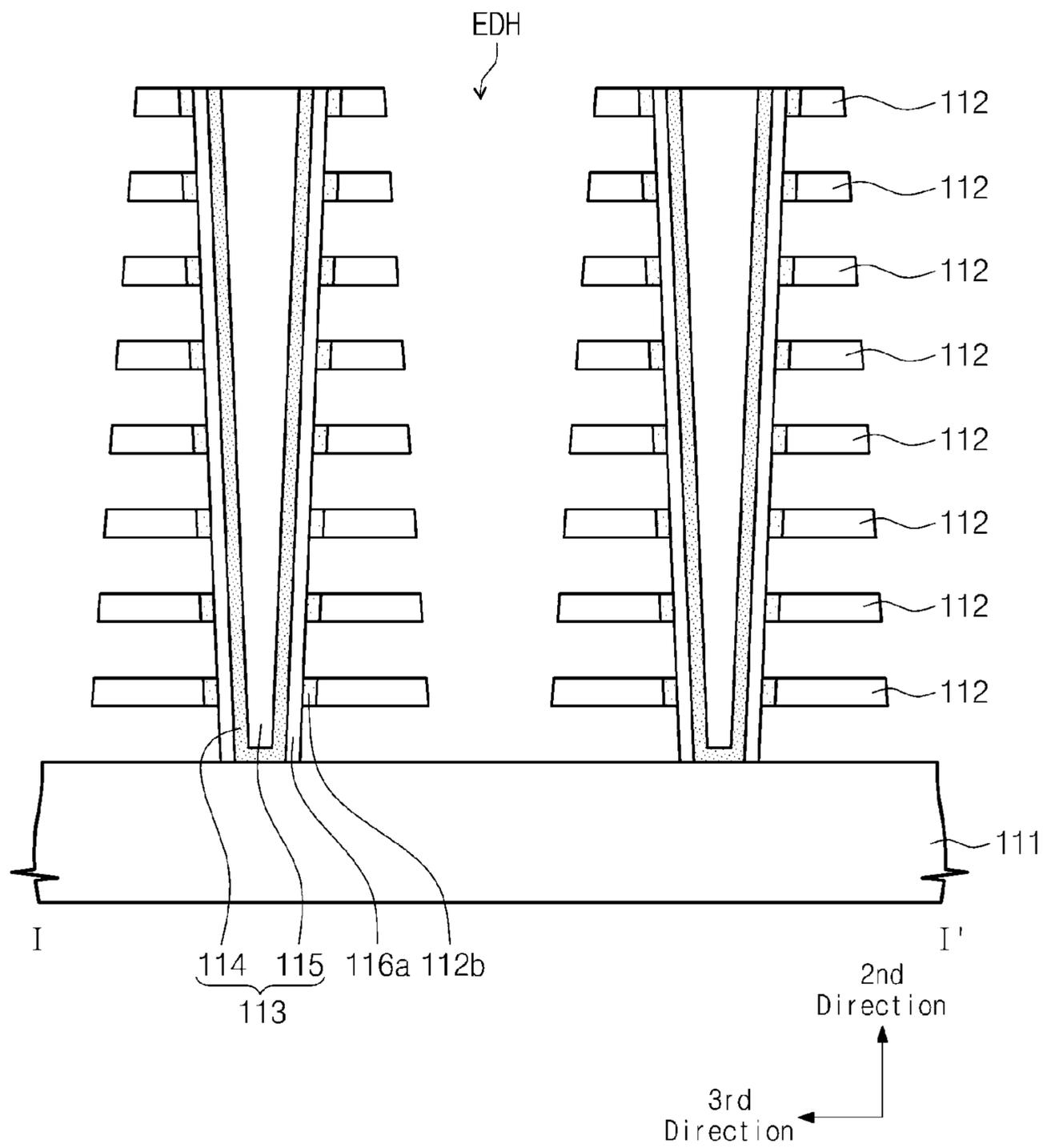


Fig. 27

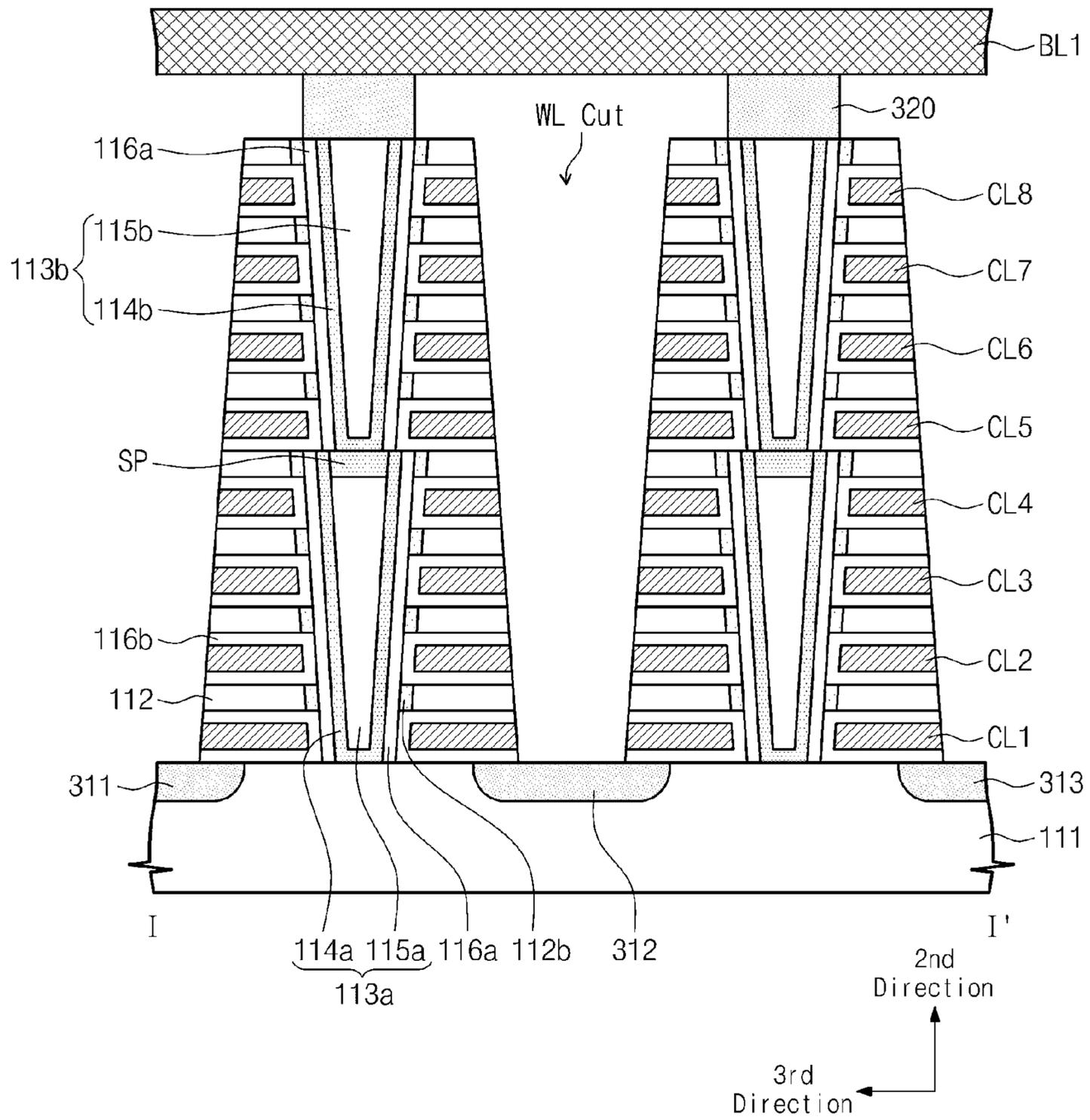


Fig. 28

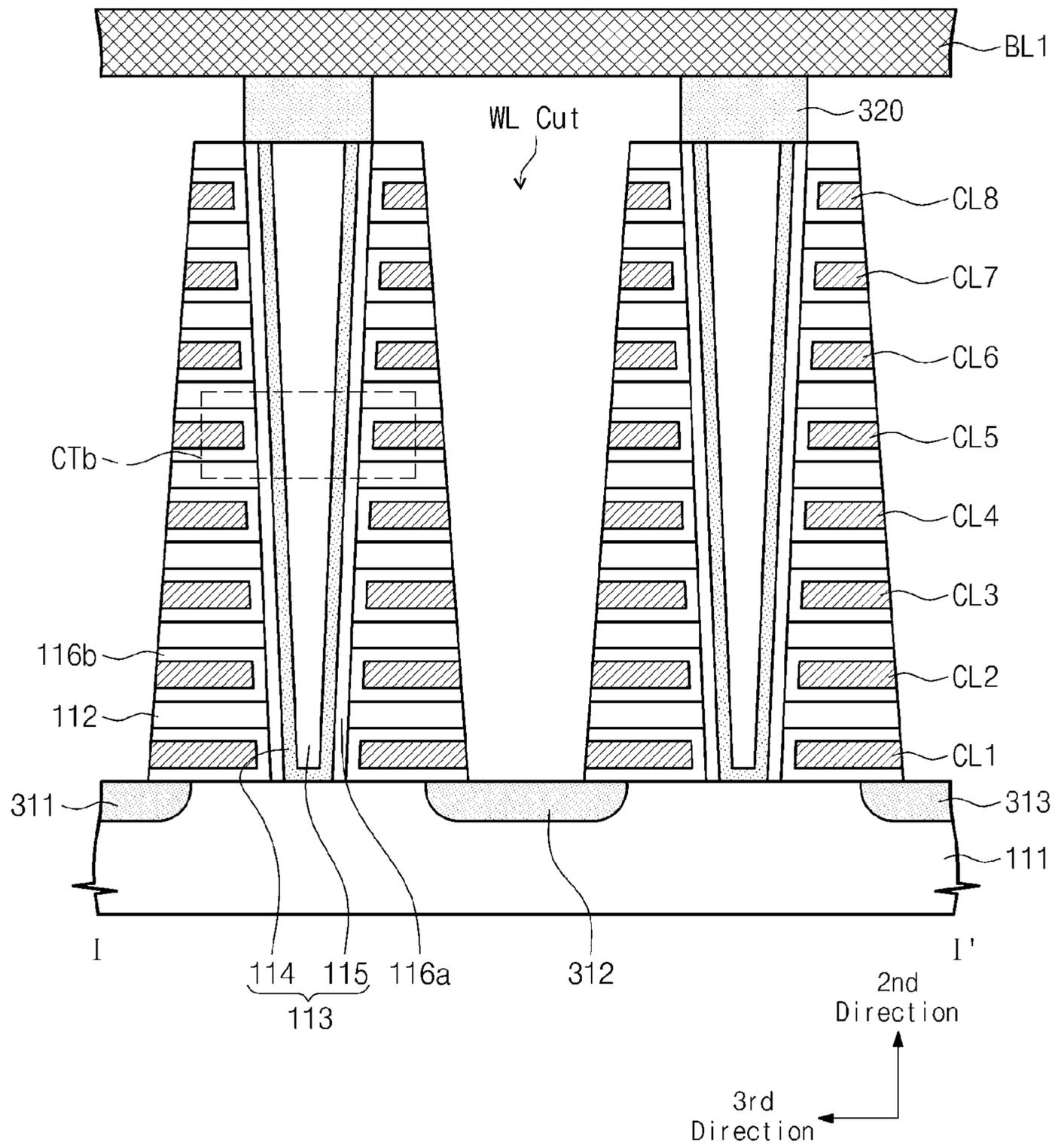


Fig. 29

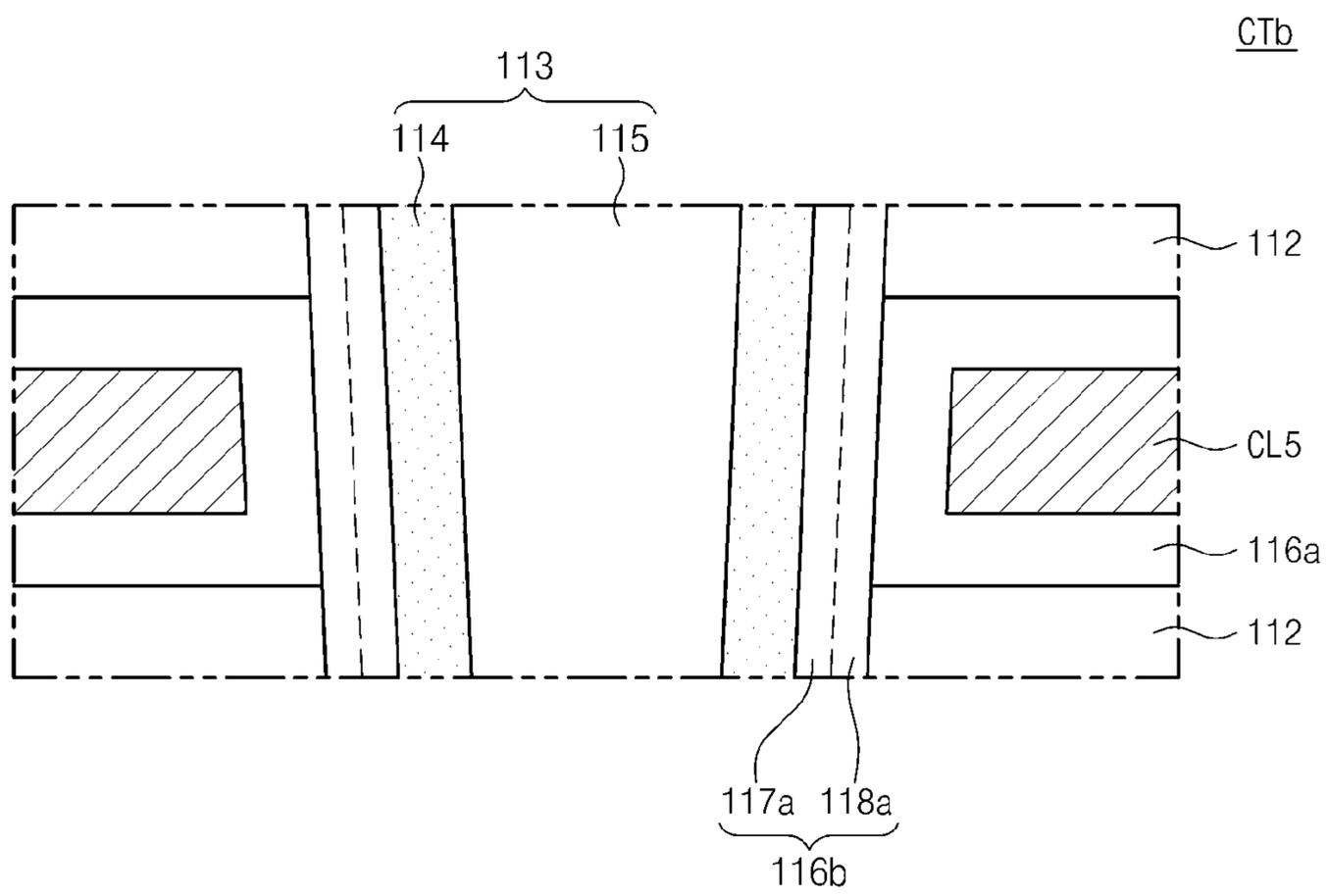


Fig. 30

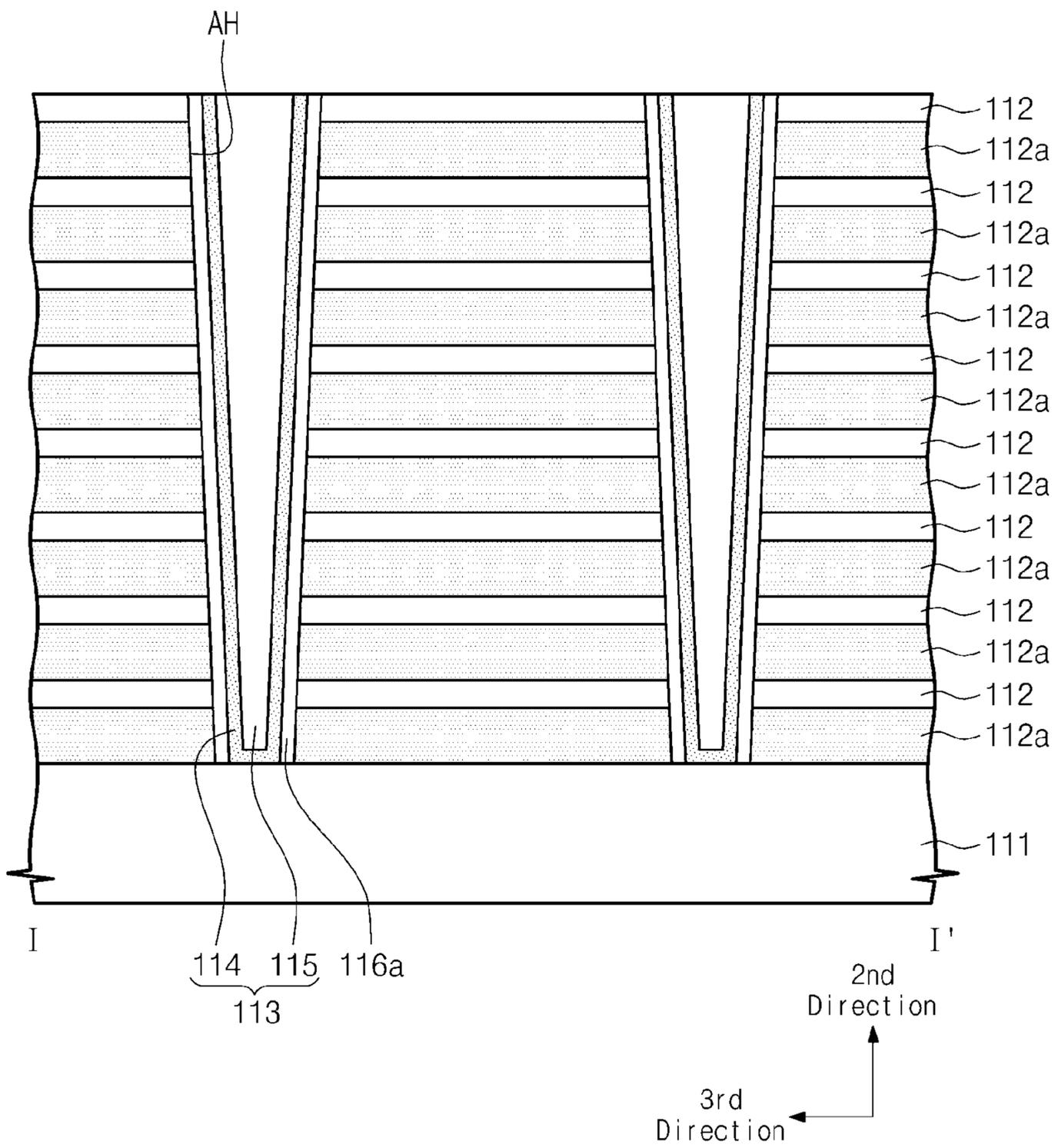


Fig. 31

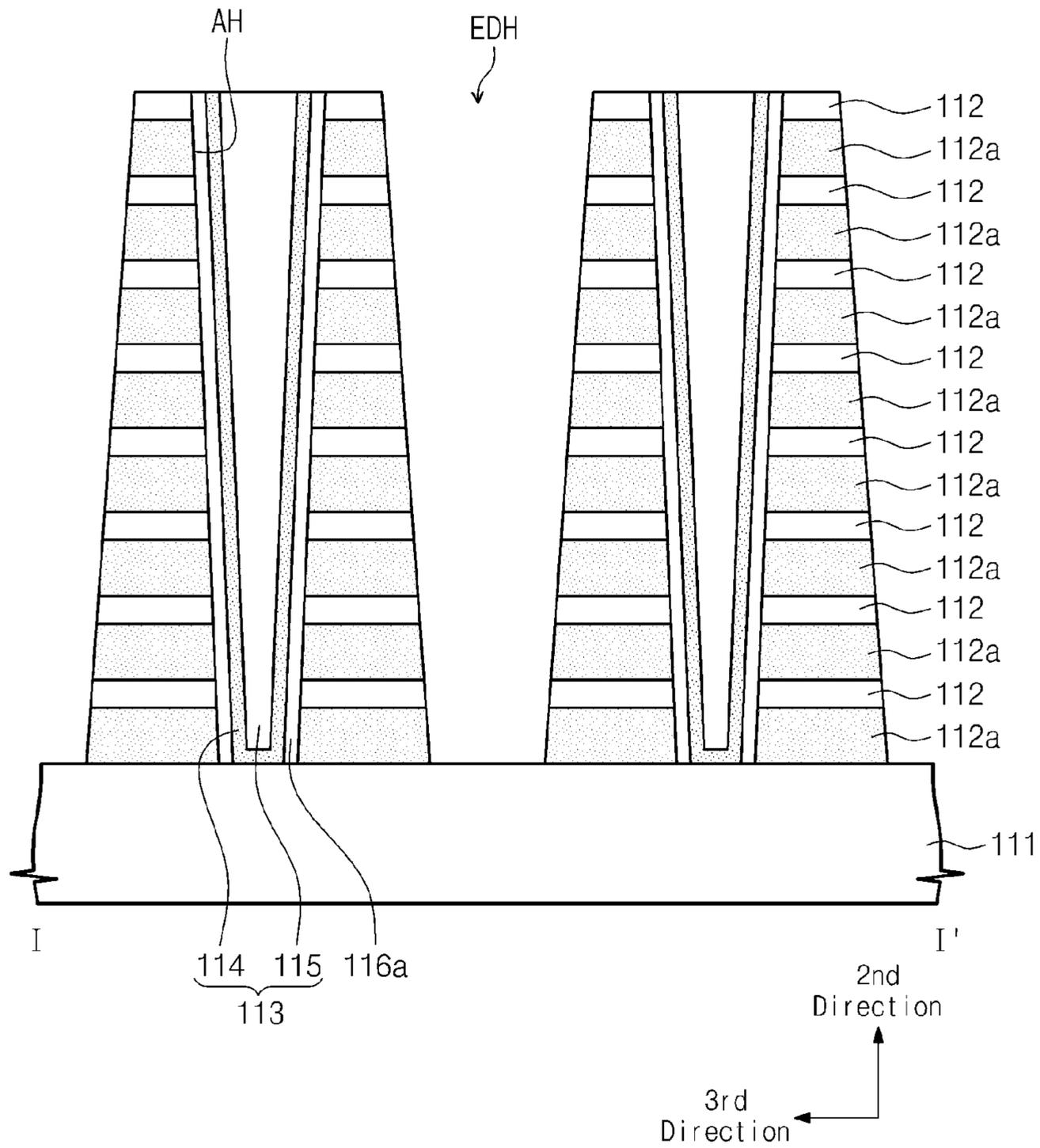


Fig. 32

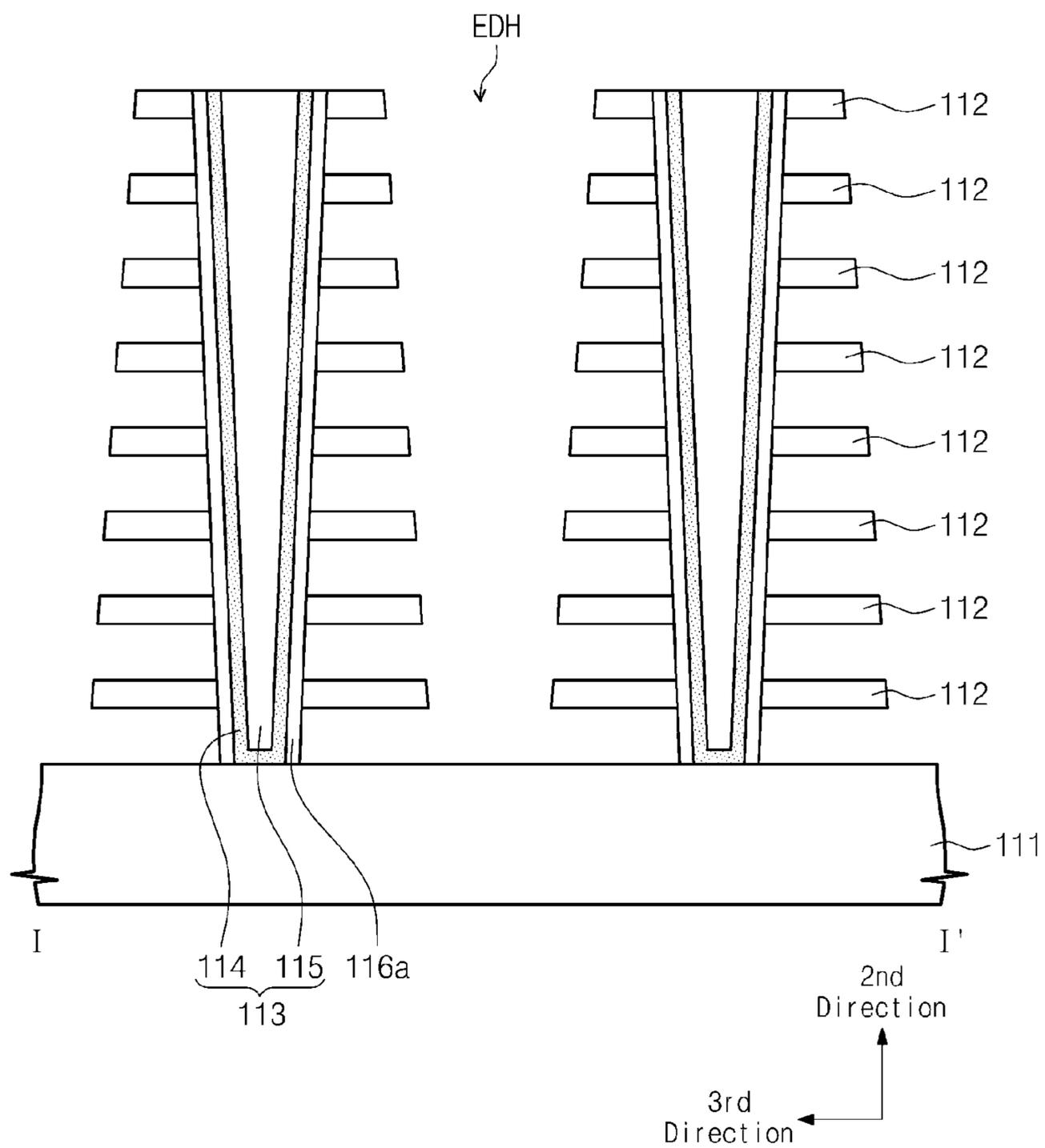


Fig. 34

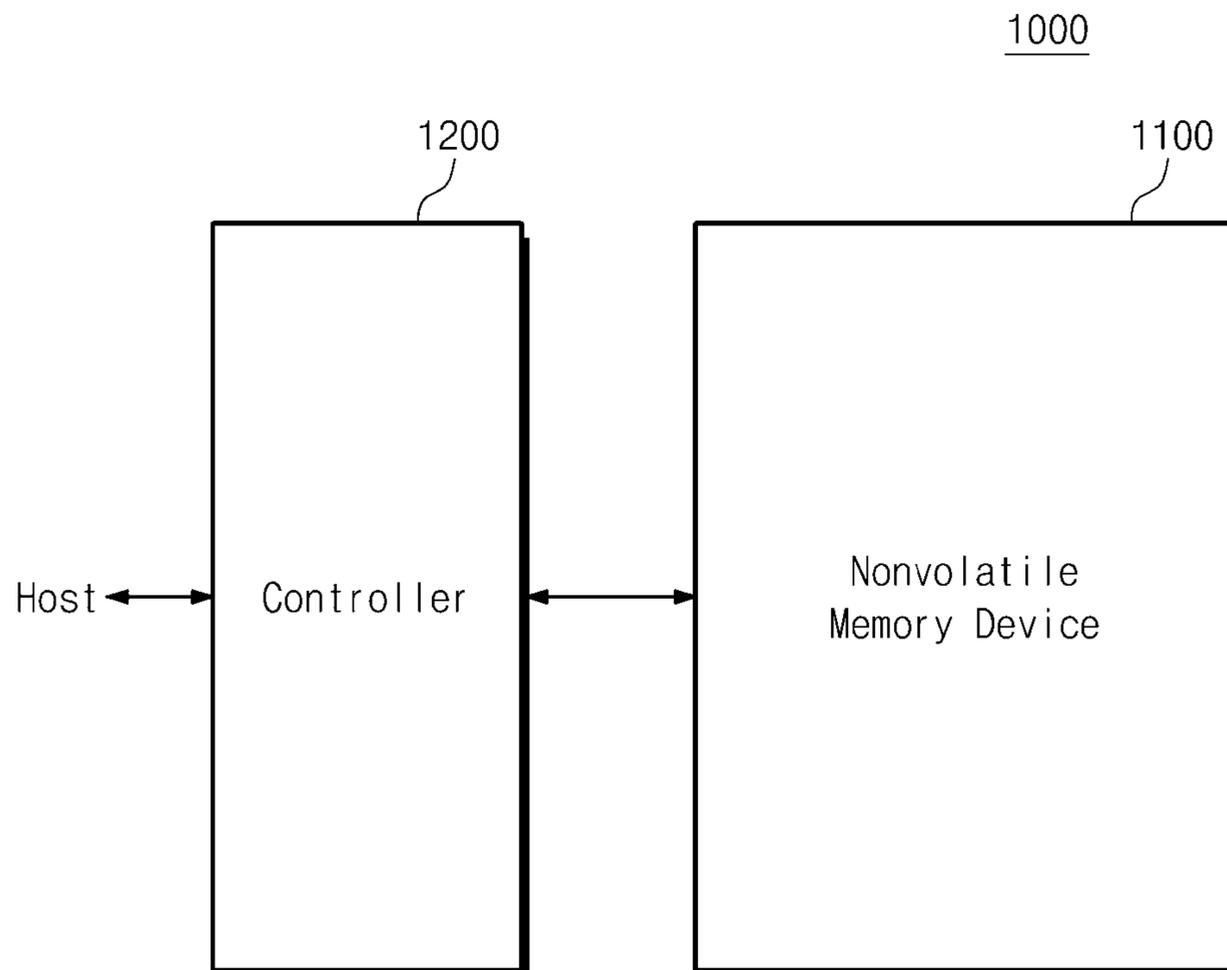


Fig. 35

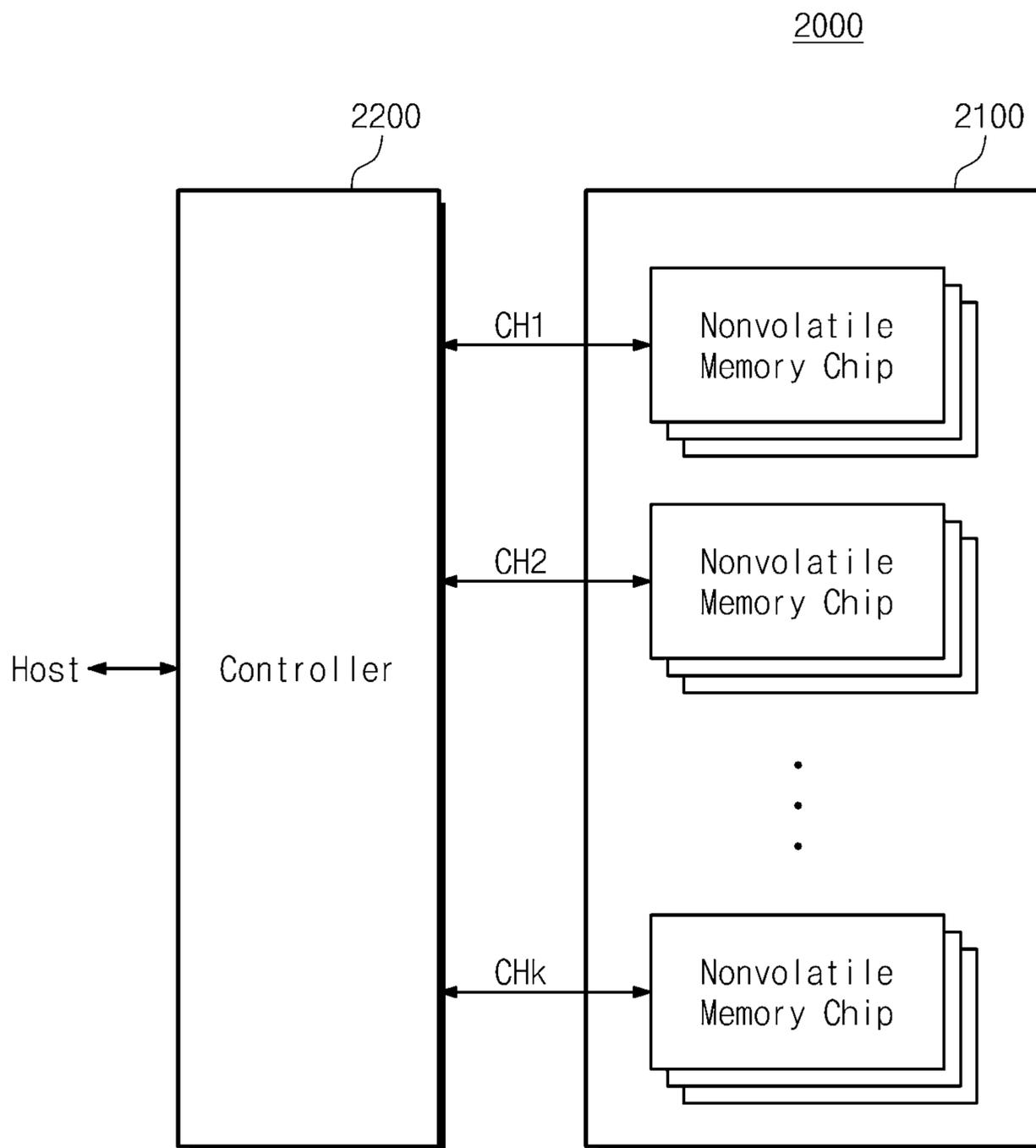
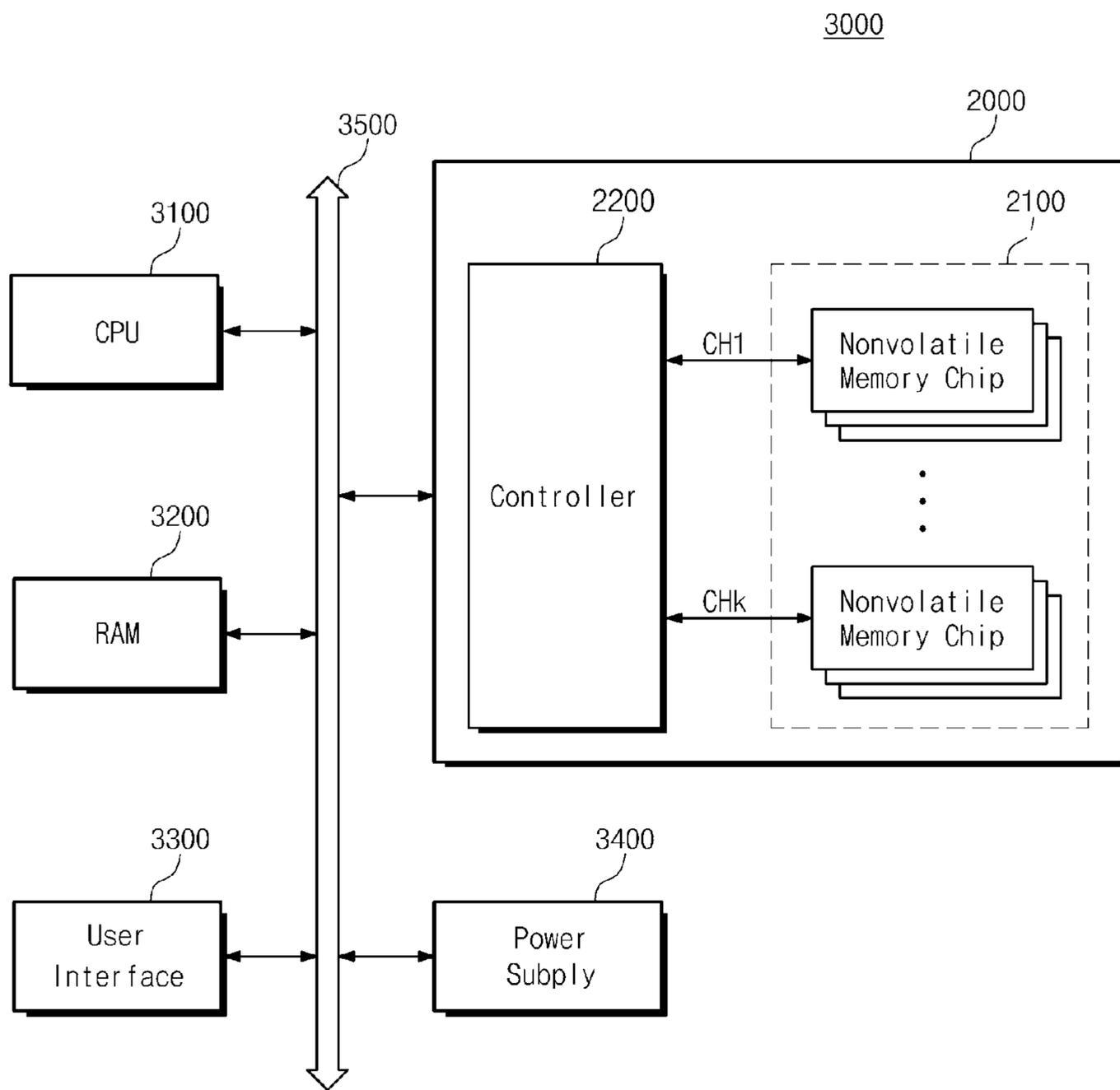


Fig. 36



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**NONVOLATILE MEMORY DEVICE IN
THREE-DIMENSIONAL STRUCTURE WITH
A STRESS REDUCING MATERIALS ON THE
CHANNEL**

CROSS-REFERENCE TO RELATED
APPLICATIONS

This US non-provisional patent application claims priority under 35 USC §119 to Korean Patent Application No. 10-2010-0106961, filed on Oct. 29, 2010, in the Korean Intellectual Property Office, and entitled "Nonvolatile Memory Device and Manufacturing Method Thereof," is incorporated by reference herein in its entirety.

BACKGROUND

A semiconductor memory device may be a memory device that is implemented with semiconductor materials such as silicon (Si), germanium (Ge), gallium arsenide (GaAs), and/or indium phosphide (InP). Semiconductor memory devices may be one of a volatile memory device and a nonvolatile memory device.

The volatile memory device may be a memory device in which stored data may be erased when a power source is shut off. Examples of volatile memory devices include Static Random Access Memory (SRAM), Dynamic Random Access Memory (DRAM), and Synchronous Dynamic Random Access Memory (SDRAM). A nonvolatile memory device may be a memory device that retains stored data even when a power source is shut off. Examples of nonvolatile memory devices include Read-Only Memory (ROM), Programmable Read Only Memory (PROM), Erasable Programmable Read Only Memory (EPROM), Electrical Erasable Programmable Read Only Memory (EEPROM), flash memory devices, Phase-change Random Access Memory (PRAM), Magnetoresistive Random Access Memory (MRAM), Resistive Random Access Memory (RRAM) and Ferroelectric Random Access Memory (FRAM). Flash memory devices may be largely categorized into a NOR type and a NAND type.

Semiconductor memory devices having a three-dimensional structure have been studied to increase integration of semiconductor devices.

SUMMARY

Embodiments may be realized by providing a nonvolatile memory device including a substrate, a stacked structure including conductive materials and first insulating materials and the conductive materials and the first insulating materials are alternately stacked on the substrate, a plurality of pillars in contact with the substrate and the pillars extend through the stacked structure in a direction perpendicular to the substrate, information storage layers between the conductive materials and the first insulating materials, and second insulating materials between the first insulating materials and the pillars.

The first insulating materials may include a semiconductor nitride. The second insulating materials may include a semiconductor oxide. The information storage layers may extend onto top and bottom surfaces of the conductive materials from between the conductive materials and the pillars. Each of the pillars may include a semiconductor layer.

The information storage layers may include first semiconductor oxide layers on outer side surfaces of the pillars, charge trapping layers on outer side surfaces of the first semiconductor oxide layers, and second semiconductor oxide lay-

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ers extending onto top and bottom surfaces of the conductive materials from between the conductive materials and the charge trapping layers.

Embodiments may also be realized by providing a non-volatile memory device including a substrate, a stacked structure including conductive materials and insulating materials, the conductive materials and the insulating materials are alternately stacked on the substrate, and the insulating materials include a semiconductor nitride. The device also includes a plurality of pillars in contact with the substrate and the pillars extend through the stacked structure in a direction perpendicular to the substrate, first semiconductor oxide layers on outer side surfaces of the pillars, charge trapping layers on outer side surfaces of the first semiconductor oxide layers, and second semiconductor oxide layers extending onto top and bottom surfaces of the conductive materials from between the conductive materials and the charge trapping layers.

Each of the pillars may include a semiconductor layer. The insulating materials may be in direct contact with the charge trapping layers.

Embodiments may also be realized by providing a stacked structure on a substrate, the stacked structure includes conductive materials and first insulating materials alternately stacked on the substrate, and the first insulating materials include a semiconductor nitride, a plurality of pillars in contact with the substrate and the pillars extend through the stacked structure in a direction perpendicular to the substrate, charge trapping layers between the conductive materials and the first insulating materials, and semiconductor oxide layers contacting the pillars.

Portions of the semiconductor oxide layers contacting the pillars may be between the first insulating materials and the pillars. The semiconductor oxide layers may be on the charge trapping layers such that the portions of the semiconductor oxide layers contacting the pillars may be between the charge trapping layers and the pillars. The semiconductor oxide layers may extend along substantially an entire length of outer walls of the pillars.

The semiconductor oxide layers may be between the conductive materials and the pillars. The device may include tunnel insulating layers on the charge trapping layers and the tunnel insulating layers may be in contact with the semiconductor oxide layers. Ones of the semiconductor oxide layers contacting one of the plurality of pillars may be spaced apart by adjacent ones of the first insulating materials.

Each pillar may include inner materials and a channel layer surrounding the inner materials and the channel layer may include a semiconductor material. The semiconductor oxide layers may be in contact with the semiconductor material of the channel layer. Each channel layer may include a lower channel layer and an upper channel layer. The lower channel layer may be directly on the substrate and the upper channel layer may be above the lower channel layer and connected to the substrate through the lower channel layer. The lower and upper channel layers of each channel layer may have ones of the semiconductor oxide layers in contact therewith.

The device may include bitlines connected to the plurality of pillars. The semiconductor oxide layers may be spaced apart from the first insulating materials by at least the charge trapping layers.

BRIEF DESCRIPTION OF THE DRAWINGS

Features will become apparent to those of ordinary skill in the art by describing in detail exemplary embodiments with reference to the attached drawings, in which:

FIG. 1 illustrates a block diagram of a nonvolatile memory device, according to an exemplary embodiment.

FIG. 2 illustrates memory blocks of a memory cell array in FIG. 1.

FIG. 3 illustrates a top plan view showing a portion of one of the memory blocks in FIG. 2.

FIG. 4 illustrates an exemplary embodiment of a cross sectional view taken along the line I-I' in FIG. 3.

FIG. 5 illustrates an enlarged view of a cell transistor in FIG. 4.

FIG. 6 illustrates a circuit diagram of an equivalent circuit of the memory block described with reference to FIGS. 3 and 4.

FIGS. 7 to 13 illustrate cross-sectional views depicting stages in an exemplary method of forming the memory block described with reference to FIGS. 3 and 4.

FIG. 14 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIGS. 15 and 16 illustrate cross-sectional depicting stages in an exemplary method of forming a memory block described with reference to FIGS. 3 and 14.

FIG. 17 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIGS. 18 and 20 illustrate cross-sectional views depicting stages in an exemplary method of forming a memory block described with reference to FIGS. 3 and 17.

FIG. 21 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIG. 22 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIG. 23 illustrates an enlarged view of a cell transistor in FIG. 22.

FIGS. 24 to 26 illustrate cross-sectional views depicting stages in an exemplary method of forming a memory block described with reference to FIGS. 3 and 22.

FIG. 27 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-P in FIG. 3.

FIG. 28 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIG. 29 illustrates an enlarged view of a cell transistor in FIG. 28.

FIGS. 30 to 32 illustrate cross-sectional views depicting stages in an exemplary method of forming a memory block described with reference to FIGS. 3 and 28.

FIG. 33 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3.

FIG. 34 illustrates a block diagram of a memory system according to an exemplary embodiment.

FIG. 35 illustrates a block diagram illustrating an application example of the memory system in FIG. 34.

FIG. 36 illustrates a block diagram of a computing system including the memory system described with reference to FIG. 35.

DETAILED DESCRIPTION

Example embodiments will now be described more fully hereinafter with reference to the accompanying drawings; however, they may be embodied in different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art.

In the drawing figures, the dimensions of layers and regions may be exaggerated for clarity of illustration. It will also be understood that when a layer or element is referred to as being “on” another layer or substrate, it can be directly on

the other layer or substrate, or intervening layers may also be present. Further, it will be understood that when a layer is referred to as being “under” another layer, it can be directly under, and one or more intervening layers may also be present. In addition, it will also be understood that when a layer is referred to as being “between” two layers, it can be the only layer between the two layers, or one or more intervening layers may also be present. Like reference numerals refer to like elements throughout.

FIG. 1 illustrates a block diagram of a nonvolatile memory device **100** according to an exemplary embodiment. As illustrated, the nonvolatile memory device **100** may include a memory cell array **110**, an address decoder **120**, a read and write circuit **130**, and a control logic **140**.

The memory cell array **110** may include a plurality of memory cell groups therein. For example, the memory cell array **110** may include a plurality of cell strings arranged on a substrate in the directions of rows and columns. Each of the cell strings may include a plurality of memory cells stacked in a direction intersecting, e.g., substantially perpendicular, to a substrate. For example, the memory cells may be provided on the substrate along rows and columns and stacked in the direction perpendicular to the substrate to constitute a three-dimensional structure. Exemplarily, the memory cell array **110** may include a plurality of memory cells capable of storing one or more bits in each cell.

The address decoder **120** may be connected to the memory cell array **110** through, e.g., wordlines WL, string selection lines SSL, and ground selection lines GSL. The address decoder **120** may be configured to operate in compliance with the control of the control logic **140**. The address decoder **120** may receive an external address ADDR.

The address decoder **120** may be configured to decode a row address of received address ADDR. The address decoder **120** may be configured to select a wordline corresponding to the decoded row address among the wordlines WL. The address decoder **120** may be configured to select a string selection line SSL and a ground selection line corresponding to the decoded row address among the string selection lines SSL and the ground selection lines GSL.

The address decoder **120** may be configured to decode a column address of the received address ADDR. The address decoder **120** may transfer the decoded column address DCA to the read and write circuit **130**.

According to an exemplary embodiment, the address decoder **120** may include a row decoder decoding a row address, a column decoder decoding a column address, and an address buffer storing the received address ADDR.

The read and write circuit **130** may be connected to the memory cell array **110** through the bitlines BL. The read and write circuit **130** may be configured to exchange data with an external entity. The read and write circuit **130** may operate in compliance with the control of the control logic **140**.

The read and write circuit **130** may receive the decoded column address DCA from the address decoder **120**. The read and write circuit **130** may select bitlines BL in response to the decoded column address DCA.

The read and write circuit **130** may be configured to externally receive data DATA and writes the received data DATA into the memory cell array **110**, according to an exemplary embodiment. The read and write circuit **130** may read the written data DATA from the memory cell array **110** and outputs the read data DATA to an external entity. The read and write circuit **130** may read data from a first storage region of the memory cell array **110** and write the read data in a second

storage region of the memory cell array **110**. For example, the read and write circuit **130** may perform a copy-back operation.

The read and write circuit **130** may include well-known elements such as a page buffer (or page register) and a column selection circuit. As another example, the read and write circuit **130** may include well-known elements such as a sense amplifier, a write driver, and a column selection circuit.

The control logic **140** may be connected to the address decoder **120** and the read and write circuit **130**. For example, the control logic **140** may be configured to control the overall operation of the nonvolatile memory device **100**.

FIG. **2** illustrates memory blocks of the memory cell array **110** in FIG. **1**. As illustrated, the memory cell array **110** may include a plurality of memory blocks BLK1-BLKz. Each memory block BLK may have a three-dimensional structure, e.g., a vertical structure. For example, each of the memory blocks BLK1-BLKz may include structures extending in each of the first to third directions. For example, each of the memory block BLK1-BLKz may include a plurality of cell strings extending in the second direction. The plurality of cell strings may be provided in the first and third directions to be spaced apart from each other at specific intervals.

The memory blocks BLK1-BLKz may be selected by the address decoder **120** illustrated in FIG. **1**. For example, the address decoder **120** may be configured to select at least one memory block BLK corresponding to the received address ADDR of the memory blocks BLK1-BLKz.

FIG. **3** illustrates a top plan view showing a portion of one memory block BLK1 among the memory blocks BLK1-BLKz in FIG. **2**. Exemplarily, a top plan view of conductive layers of the memory block BLK1 is shown in FIG. **3**. Others of the memory blocks BLK may have a similar or substantially a same top plan view. FIG. **4** illustrates an exemplary embodiment of a cross sectional view taken along the line I-I' in FIG. **3**.

Referring to FIGS. **3** and **4**, the memory block BLK1 may include structures extending in the first to third directions. A substrate **111** may be provided. The substrate **111** may be, e.g., a well having a first conductivity type. For example, the substrate **111** may be a p-type well formed by implanting Group III elements such as boron (B) therein. However, embodiments are not limited thereto. For example, the substrate **111** may be a p-type pocket well provided in an n-type well. Hereinafter, for ease of explanation the substrate **111** is referenced as including a p-type well (or pocket p-well). However, the conductivity type of the substrate **111** is not limited to the p-type well.

A plurality of doping regions **311-313** may be provided on the substrate **111**. The doping regions **311-313** may extend in a first direction, e.g., may extend in the first direction substantially parallel to each other. The doping regions **311-313** may be arranged on the substrate **111** in a third direction to be spaced apart from each other at specific intervals. The doping regions **311-313** may be sequentially defined as a first doping region **311**, a second doping region **312**, and a third doping region **313**.

The doping regions **311-313** may have a second conductivity type differing from that of the substrate **111**. For example, the first to third doping regions **311-313** may have a n-type conductivity. For ease of explanation, the first to third doping regions **311-313** are referenced as including the n-type conductivity. However, the conductivity types of each of the first to third doping regions **311-313** is not limited to the n-type.

Between adjacent two doping regions among the first to third doping regions **311-313**, a plurality of first insulating

materials **112** may be sequentially provided on the substrate **111**. The plurality of first insulating materials **112** may be stacked in the second direction (e.g., a direction perpendicular to the substrate **111**). A stacked structure may include the first insulating materials **112** spaced apart from each other in the second direction at specific intervals. The first insulating material **112** may extend in the first direction e.g., in a direction substantially parallel to the substrate **111**. The first insulating materials **112** may include an insulating material such as a nitride, e.g., a semiconductor nitride.

Between adjacent doping regions among the first to third doping regions **311-313**, pillars **113** may be arranged in the first direction to penetrate the first insulating materials **112** in the second direction. For example, the pillars **113** may be in contact with the substrate **111** through the first insulating materials **112**.

Each of the pillars **113** may include a plurality of materials, according to an exemplary embodiment. For example, a channel layer **114** of each pillar **113** may include a first-type semiconductor material (e.g., silicon). The channel layer **114** of each pillar **113** may include a semiconductor material (e.g., silicon) having the same conductivity type as the substrate **111**. Hereinafter, for ease of explanation it is referenced that the channel layer **114** of each pillar **113** includes p-type silicon. However, the channel layer **114** of each pillar **113** is not limited to including the p-type silicon. For example, the channel layer **114** of each pillar **113** may include an intrinsic semiconductor having no conductivity type.

An inner material **115** of each pillar **113** may include an insulating material. For example, the inner material **115** of each pillar **113** may include an insulating material such as silicon oxide. The inner material **115** of each pillar **113** may include an air gap therein.

Between adjacent doping regions among the first to third doping regions **311-313**, an information storage layer **116** may be arranged on exposed surfaces of the first insulating materials **112** and the pillars **113**. According to an exemplary embodiment, a thickness of the information storage layer **116** may be less than half the distance between the first insulating materials **112**.

Between adjacent doping regions among the first to third doping regions **311-313**, first conductive materials CL1-CL8 may be provided on exposed surfaces of the information storage layer **116**. The conductive materials CL1-CL8 may extend in the first direction. Each conductive material of the conductive materials CL1-CL8 may be provided between two adjacent first insulating materials of the first insulating materials **112**. The conductive materials CL1-CL8 may include a metallic conductive material. The conductive materials CL1-CL8 may include, e.g., a non-metallic conductive material such as polysilicon.

On the doping regions **311-313**, the conductive materials CL1-CL8 may be divided, e.g., spaced apart, by a wordline cut WL Cut. For example, adjacent stacked structures arranged along the third direction, of which each stacked structure may include the first insulating materials **112** and the conductive materials CL1-CL8, may have the wordline cut WL Cut therebetween. The wordline cut WL Cut may overlap a portion of one of the first to third doping regions **311-313**.

According to an exemplary embodiment, the information storage layers **116** provided on a top surface of an uppermost insulating material of the first insulating materials **112** may be removed. The information storage layers **116** provided on a side surface facing the pillars **113** among side surfaces of the insulating materials **112** may be provided, e.g., may remain.

A plurality of drains **320** may be provided on the pillars **113**, respectively. Each drain **320** may correspond to one pillar **113**. The drains **320** may extend to an upper portion of the channel layer **114** of each pillar **113**. Exemplarily, each of the drains **320** may include a second-type semiconductor material (e.g., silicon). For example, each of the drains **320** may include an n-type semiconductor material (e.g., silicon). Hereinafter, for ease of explanation it will be referenced that each of the drains **320** includes n-type silicon. However, each of the drains **320** is not limited to including the n-type silicon.

Bitlines **BL1** and **BL2** may be provided on the drains **320**. The bitlines **BL1** and **BL2** may extend in a third direction above the pillars **113**. The bitlines **BL1** and **BL2** may be spaced apart from each other at specific intervals. The bitlines **BL1** and **BL2** may be connected, e.g., electrically connected, to the drains **320**. The drains **320** and the bitlines **BL1** and **BL2** may be connected to each other through contact plugs (not shown) or may be in direct contact with each other. The bitlines **BL1** and **BL2** may include metallic conductive materials. Exemplarily, the bitlines **BL1** and **BL2** may include non-metallic conductive materials such as polysilicon.

Hereinafter, rows and columns of the pillars **113** of the memory block **BLK1** are defined. The rows of the pillars **113** may be defined depending on whether the conductive materials **CL1-CL8** are divided. In FIGS. **3** and **4**, it is shown that the conductive materials **CL1-CL8** may be divided on the basis of the doping region **312**, according to an exemplary embodiment.

Pillars **113** coupled through the conductive materials **CL1-CL8** and the information storage layers **116** provided between the first doping region **311** and the second doping region **312** may be defined as first-row pillars. Pillars **113** coupled through the conductive materials **CL1-CL8** and the information storage layers **116** provided between the second doping region **312** and the third doping region **313** may be defined as second-row pillars.

The columns of the pillars **113** may be defined according to the bitlines **BL1** and **BL2**. Pillars **113** coupled through the first bitline **BL1** and the drain **320** may be defined as first-column pillars. Pillars **113** coupled through the second bitline **BL2** and the drain **320** may be defined as second-column pillars.

Hereinafter, heights of the conductive materials **CL1-CL8** are defined. The conductive materials **CL1-CL8** may be defined as first to eighth conductive materials **CL1-CL8** according to the order from the substrate **111**. Accordingly, the first to eighth conductive materials **CL1-CL8** may have first to eighth heights, respectively, with respect to the substrate **111**. Each of the first to eighth heights may be different.

In FIGS. **3** and **4**, the pillars **113** may constitute a plurality of cell strings **CS** together with the information storage layers **116** and the conductive materials **CL1-CL8**. Each pillar **113** may constitute one cell string **CS** together with the adjacent information storage layers **116** and adjacent conductive materials **CL1-CL8**.

Pillars **113** may be arranged on the substrate **111** in the column and row directions. For example, the memory block **BLK1** may include a plurality of cell strings **CS** disposed on the substrate **111** in the row and column directions. Each of the cell strings **CS** may include a plurality of cell transistors **CT** stacked in a direction perpendicular to the substrate **111**. The cell transistors **CT** will be described below in detail with reference to FIG. **5**.

FIG. **5** illustrates an enlarged view of one of the cell transistors **CT** in FIG. **4**. Referring to FIGS. **3** to **5**, of the cell transistors, a cell transistor having a fifth height may include the fifth conductive material **CL5**, a portion of a pillar **113**

corresponding to the fifth conductive material **CL5**, and information storage layers **116** provided between the fifth conductive material **CL5** and pillars **113**.

The information storage layers **116** may extend to top and bottom surfaces of the conductive materials **CL1-CL8** from between the conductive materials **CL1-CL8** and the pillars **113**. The information storage layers **116** may include at least one of first to third sub layers, e.g., sub-insulating layers, **117**, **118**, and **119**, e.g., as illustrated in FIG. **5**.

In the cell transistors **CT**, channel layers **114** of the pillars **113** may include, e.g., the same p-type silicon as the substrate **111**. The channel layers **114** may act as a body in the cell transistor **CT**. The channel layers **114** may be formed in a direction perpendicular to the substrate **111**. Accordingly, the channel layers **114** of the pillars **113** may be defined to act as a vertical body. A channel region formed at the channel layers **114** of the pillars **113** may be a vertical channel.

A first sub layer **117** may be adjacent to the pillars **113** and may act as a tunneling insulating layer, e.g., may be an insulating material. For example, the first sub layer **117** may be adjacent to the pillars **113** and may include a thermal oxide and/or a semiconductor oxide. According to an exemplary embodiment, the first sub layer **117** may include, e.g., silicon oxide.

A second sub layer **118** may act as a charge storage layer. For example, the second sub layer **118** may act as a charge trapping layer. The second sub layer **118** may include, e.g., a nitride and/or a metal oxide (e.g., aluminum oxide, hafnium oxide, etc.). The second sub layer **118** may include, e.g., silicon oxide.

A third sub layer **119** adjacent to the conductive material **CL5** acts as a blocking insulating layer. For example, the third sub layer **119** may have a single-layer structure or a multi-layer structure. The third sub layer **119** may be a high-k dielectric layer (e.g., aluminum oxide layer, hafnium oxide layer, etc.) having a higher dielectric constant than the first and second sub layers **117** and **118**. The third sub layer **119** may include, e.g., silicon oxide.

According to an exemplary embodiment, the first to third sub layers **117**, **118**, and **119**, e.g., sub-insulating layers, may constitute an oxide-nitride-oxide (ONO) structure.

The fifth conductive material **CL5** may act as a gate (or control gate). For example, the fifth conductive material **CL5** acting as the gate (or control gate), the third sub layer **119** acting as the blocking insulating layer, the second sub layer **118** acting as the charge storage layer, the first sub layer **117** acting as a tunneling insulating layer, and the channel layer **114** acting as a vertical body act together may act as a cell transistor. For example, the fifth conductive material **CL5**, the third sub layer **119**, the second sub layer **118**, the first sub layer **117**, and the channel layer **114** may act as a charge trap type cell transistor.

In each cell string **CS**, cell transistors **CT** therein may be differently used according to their heights. For example, among the cell transistors **CT**, at least one cell transistor provided at an upper portion of the cell string **CS** may be used as a string selection transistor **SST**. Among the cell transistors **CT**, at least one cell transistor provided at a lower portion of the cell may be used as a ground selection transistor **GST**. The other cell transistors may be used as a memory cell and a dummy memory cell.

The conductive materials **CL1-CL8** may extend in a row direction (first direction) to be coupled to a plurality of pillars in the row direction. For example, the conductive materials **CL1-CL8** and the pillars **113** may constitute a plurality of cell strings **CS** that are spaced at specific intervals in the row direction. The conductive materials **CL1-CL8** may constitute

conductive lines connecting cell transistors CT having the same height of cell strings CS of the same row.

According to an exemplary embodiment, the conductive materials CL1-CL8 may each be used as one of a string selection line SSL, a ground selection line GSL, a wordline WL, or a dummy wordline DWL.

As described with reference to FIG. 5, the second sub layer 118 of each information storage layer 116 may act as a charge trapping layer. For example, the amount of electrons trapped to the second sub layer 118 may be changed when the cell transistors CT are programmed or erased.

Exemplarily, a fifth cell transistor formed by the fifth conductive material CL5 and a sixth cell transistor formed by the sixth conductive material CL6 may be different in threshold voltage. For example, an electric field may be established between the second sub layer 118 of the fifth cell transistor and the second sub layer 118 of the sixth cell transistor. The electric field may allow the electrons trapped to the second sub layer 118 to spread out. This phenomenon is called "spreading".

Without intending to be bound by this theory, when the electrons trapped to the second sub layer 118 spread out, a threshold voltage of the cell transistors CT may be shifted. That is, e.g., data stored in the cell transistors CT may be lost.

However, according to an exemplary embodiment, the first insulating materials 112 may be provided between the conductive materials CL1-CL8. As described above, the first insulating materials 112 may include a nitride, e.g., a semiconductor nitride. Since the semiconductor nitride itself may have negative characteristics, an electric field between the conductive materials CL1-CL8 may be attenuated, e.g., confined to a predetermined area, by the first insulating materials 112. For example, since the spreading may be reduced and/or prevented by the first insulating materials 112 including the semiconductor nitride, reliability of the nonvolatile memory device (100 in FIG. 1) may be enhanced.

FIG. 6 illustrates a circuit diagram of an equivalent circuit of the memory block BLK1 described with reference to FIGS. 3 and 4. Referring to FIGS. 3 to 6, cell strings CS11 and CS21 may be provided between the first bitline BL1 and the common source line CSL, e.g., the cell strings CS11 and CS21 may be electrically connected to the first bitline BL1. Cell strings CS12 and CS22 may be provided between the second bitline BL2 and the common source line CSL, e.g., the cell strings CS12 and CS22 may be electrically connected to the second bitline BL2. The cell strings CS11, CS21, CS12, and CS22 may correspond to the pillars 113, respectively.

In the cell strings CS11, CS12, CS21, and CS22, first cell transistors may act as ground selection transistors, respectively. Cell strings of the same row may share a ground selection line GSL. Cell strings of different rows share ground selection lines GSL. The first conductive materials CL1 may be connected to each other to form a ground selection line.

In the cell strings CS11, CS12, CS21, and CS22, second to sixth transistors may act as memory cells MC1-MC6. Memory cells having substantially the same height, e.g., from the substrate, and corresponding to the same row may share a wordline WL. Memory cells MC having substantially the same height and corresponding to different rows may share wordlines WL. That is, memory cells having the same height may share wordlines WL.

According to an exemplary embodiment, ones of the second conductive materials CL2 may be commonly connected to form a first wordline WL1. Ones of the third conductive materials CL3 may be commonly connected to form a second wordline WL2. Ones of the fourth conductive materials CL4 may be commonly connected to form a third wordline WL3.

Ones of the fifth conductive materials CL5 may be commonly connected to form a fourth wordline WL4. Ones of the sixth conductive materials CL6 may be commonly connected to form a fifth wordline WL5. Ones of the seventh conductive materials CL7 may be commonly connected to form a sixth wordline WL6.

In the cell strings CS11, CS12, CS21, and CS22, eighth cell transistors may operate as string selection transistors. Cell strings of the same row may share a string selection line SSL. Cell strings of different rows may be connected to different string selection lines. The first and second string selection lines SSL1 and SSL2 may correspond to the eighth conductive materials CL8. For example, it may be understood that the pillars 113, e.g., rows of cell strings, may be defined by the string selection lines SSL1 and SSL2.

Hereinafter, string selection transistors SST connected to the first string selection line SSL1 are defined as first string selection transistors SST, and string selection transistors SST connected to the second string selection line SSL2 are defined as second string selection transistors SST.

The common source line CSL may be commonly connected to cell strings. For example, the first to third doping regions 311-313 may be connected to each other to form the common source line CSL.

As illustrated in FIG. 6, wordlines WL having the same height may be connected in common. For example, when a wordline WL having a specific height is selected, all cell strings connected to the selected wordline WL may be selected.

Cell strings of different rows may be connected to different string selection lines SSL. Accordingly, by selecting and unselecting the string selection lines SSL1 and SSL2, among cell strings connected to the same wordline WL, cell strings of an unselected row may be electrically insulated from a corresponding bitline BL and cell strings of a selected row may be electrically connected to the corresponding bitline BL.

For example, rows of cell strings CS may be selected by selecting and unselecting the string selection lines SSL1 and SSL2. In addition, columns of cell strings CS of a selected row may be selected by selecting the bitlines BL1 and BL2.

Exemplarily, at least one of the wordlines WL may be used as a dummy wordline DWL. For example, at least one of a wordline WL having a height adjacent to the string selection line SSL, a wordline WL having a height adjacent to the ground selection line GSL, a wordline having a height between the string selection line SSL and the ground selection line GSL may be used as a dummy wordline DWL.

Conductive materials corresponding to at least two heights may constitute string selection lines SSL. For example, the seventh conductive materials CL7 and the eighth conductive materials CL8 may constitute string selection lines SSL, respectively. In this case, the seventh and eighth conductive materials CL7 and CL8 provided at the same row and having different heights may be commonly connected to one string selection line SSL.

Conductive materials corresponding to at least two heights may constitute a ground selection line GSL. For example, the first conductive materials CL1 and the second conductive materials CL2 may be commonly connected to constitute a ground selection line GSL. The first conductive materials CL1 may each constitute two ground selection lines GSL electrically insulated from each other.

FIGS. 7 to 13 illustrate cross-sectional views depicting stages in a procedure of forming the memory block BLK1 described with reference to FIGS. 3 and 4. Referring to FIG. 7, second insulating materials 112a and first insulating materials 112 may be alternately stacked on a substrate 111 to form

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a stacked structure. For example, the second insulating material **112a** may first be stacked on, e.g., directly on, the substrate **111** and the first insulating layer **112** may be stacked on the second insulating material **112a**. Then, the first insulating layer **112** may be stacked on the second insulating material **112a**, and the second insulating material **112a** may be stacked on the first insulating layer **112**. The second insulating materials **112a** may include, e.g., silicon oxide. The first insulating materials **112** may include silicon nitride.

Referring to FIG. **8**, active holes AH may be formed through the first and second insulating materials **112** and **112a** in a direction perpendicular to the substrate **111**. The active holes AH may be formed to expose the substrate **111**. The active holes AH may be spaced apart in the row and column directions.

Channel layers **114** may be formed on inner surfaces of the active holes AH, respectively. The channel layers **114** may have the same conductivity type. The channel layers **114** may include, e.g., intrinsic or undoped semiconductor material. Inner materials **115** may be provided in the channel layers **114**, respectively. The inner materials **115** may include, e.g., a semiconductor oxide, a semiconductor nitride, and/or an insulating material such as air gap. The inner materials **115** may fill the active holes AH including the channel layers **114**. One channel layer and one inner material in a specific active hole may together constitute one pillar **113**. For example, the channel layers **114** and the inner materials **115** constitute pillars **113**, respectively.

Referring to FIG. **9**, electrode dividing holes EDH may be formed through the first and second insulating materials **112** and **112a** in the direction perpendicular to the substrate **111**. The electrode dividing holes EDH may be formed to expose the substrate **111**. Each electrode dividing hole EDH may be disposed between adjacent pillars **113**. For example, the electrode dividing holes EDH may extend between pillars **113** in the first direction. That is, the electrode dividing holes EDH may divide the first and second insulating materials **112** and **112a** in the first direction and/or divide the pillars **113** in the first direction. The electrode dividing holes EDH may extend in the second direction, e.g., the electrode dividing hole EDH may be between two adjacent rows of the pillars **113** extending in the second direction.

Referring to FIG. **10**, the second insulating materials **112a** may be selectively removed among the first and second insulating materials **112** and **112a**. For example, the second insulating materials **112a** may be removed by injecting a material having an etching selectivity with respect to the first and second insulating materials **112** and **112a** through the electrode dividing holes EDH. Thereafter, a top surface of the substrate **111**, outer side surfaces of the pillars **113**, top surfaces and bottom surfaces of the first insulating materials **112**, and side surfaces of the first insulating materials **112** facing the adjacent pillars **113** may be exposed.

Referring to FIG. **11**, storage information layers **116** may be formed, e.g., conformally formed, on the exposed surfaces of the substrate **111**, the top and bottom surfaces of the first insulating materials **112**, the and the pillars **113**. For example, the information storage layers **116** may be conformally formed on the top surface of the substrate **111**, the outer side surfaces of the pillars **113**, the top and bottom surfaces of the first insulating materials **112**, and the side surfaces of the first insulating materials **112** facing the adjacent pillars **113**.

Referring to FIG. **12**, a conductive layer CM may be formed on exposed surfaces of the information storage layers **116**. The conductive layer CM may fill the electrode dividing holes EDH (in FIG. **11**) and may fill spaces between the first insulating materials **112**. For example, the conductive layer

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CM may fill a space between the information storage layers **116**, e.g., in regions where the second insulating materials **112a** were previously situated.

Referring to FIG. **13**, portions of the information storage layers **116** and the conductive layer CM formed on an uppermost insulating material of the first insulating materials **112** may be removed by means of, e.g., a planarization process. For example, the information storage layers **116** and the conductive layer CM may remain in regions where the second insulating materials **112a** were previously situated, e.g., in the voids left by removing the second insulating materials **112a**. A wordline cut WL Cut may be formed through the first insulating materials **112** and the conductive layer CM in the direction perpendicular to the substrate **111**. The wordline cut WL Cut may be formed to expose the substrate **111**, e.g., by removing portions of the information storage layers **116** and the conductive layer CM filling the electrode dividing holes EDH. The wordline cut WL Cut may extend between the pillars **113** in the first direction. For example, the wordline cut WL Cut may divide the first insulating material **112** and the conductive layer CM in the first direction. From another standpoint, the wordline cut WL Cut may divide the pillars **113**. The conductive layer CM may be divided by the wordline cut WL Cut to form conductive materials CL1-CL8 that are spaced apart.

The wordline cut WL Cut may be formed in a region corresponding to an electrode dividing hole (EDH in FIG. **11**). For example, among the information storage layers **116**, portions of the information storage layer **116** provided on side surfaces facing the pillars **113** of the first insulating materials **112** may be removed when the wordline cut WL Cut is formed. The wordline cut WL Cut may have sloped outer walls such that a width thereof in the third direction may increase as a distance from the substrate increases. Accordingly, a width of the conductive materials CL1-CL8 in the third direction may decrease as a distance from the substrate increases.

Returning to FIG. **4**, specific elements, e.g., impurities, may be injected through the wordline cut WL Cut to form the doping regions **311-313**. The doping regions **311-313** may have a different conductivity type than the substrate **111**. Thereafter, the wordline cut WL Cut may be filled with an insulating material.

Drains **320** may be formed on the pillars **113**. The drains **320** may include a semiconductor material having a different conductivity type than the channel layer **114**. The pillars **113** may include a semiconductor material having a different conductivity type than the doping regions **311-313**. The drains **320** may extend onto the channel layers **114** of the pillars **113**. For example, the drains **320** may overlap upper surfaces of both the channel layer **114** and the inner materials **115** in the pillars **113**.

Bitlines BL1 and BL2 may be formed on the drains **320**. The bitlines BL1 and BL2 may include a conductive material such as polysilicon and/or a metallic material. If the doping regions **311-313**, the drains **320**, and the bitlines BL1 and BL2 are formed, a nonvolatile memory device including the memory block BLK1 having the structure described with reference to FIGS. **3** and **4** may be provided.

FIG. **14** illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. **3**. Referring to FIGS. **3** and **14**, the memory block BLK1 includes structures extending in the first to third directions.

The configuration shown in FIG. **14** is similar to the configuration shown in FIG. **4**, except that pillars include first sub-pillars **113a** and second sub-pillars **113b** on the first sub-pillars **113a**. According to an exemplary embodiment,

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first insulating materials **112** provided between conductive materials **CL1-CL8** may have negative characteristics. Thus, the possibility of spreading may be reduced and/or prevented to, e.g., help improve reliability of a nonvolatile memory device (**100** in FIG. 1).

First channel layers **114a** of the first sub-pillars **113a** may include the same material as described with reference to channel layers **114** of the pillars **113**. Second channel layers **114b** of the second sub-pillars **113b** may include the same material as described with reference to channel layers **114** of the pillars **113**.

First inner materials **115a** of the first sub-pillars **113a** may include the same material as described with reference to inner materials **115**. Second inner materials **115b** of the second sub-pillars **113b** may include the same material as described with reference to inner materials **115**.

Semiconductor pads **SP** may be provided on the first sub-pillars **113a**. The first channel layers **114a** of the first sub-pillars **113a** and the second channel layers **114b** of the second sub-pillars **113b** may be connected to each other through the semiconductor pads **SP**, respectively.

Among the conductive materials **CL1-CL8**, conductive materials having a height corresponding to that of the semiconductor pads **SP**, e.g., the fourth conductive pads **CL4**, the fifth conductive pad **CL5**, or the fourth and fifth conductive pads **CL4** and **CL5** may be used with and/or as dummy wordlines **DWL**.

FIGS. **15** and **16** illustrate cross-sectional views depicting stages in a procedure for forming the memory block **BLK1** described with reference to FIGS. **3** and **14**. Referring to FIG. **15**, second insulating materials **112a** and first insulating materials **112** may be alternately stacked on the substrate **111**. For example, a second insulating material **112a** may be stacked on, e.g., directly on, the substrate **111** and a first insulating material **112** may be stacked on the second insulating material **112a**. Thereafter, the first insulating material **112** may be stacked on the second insulating material **112a**, and the second insulating material **112a** may be stacked on the first insulating material **112**. The second insulating materials **112a** and the first insulating materials **112** may be alternately stacked to a specific height. The second insulating materials **112a** may include, e.g., semiconductor oxide. The first insulating materials **112** may include, e.g., semiconductor nitride.

First active holes **AH1** may be formed through the first and second insulating materials **112** and **112a** in a direction perpendicular to the substrate **111**. The first active holes **AH1** may be formed to expose the substrate **111**.

First channel layers **114a** may be formed on inner surfaces of the first active holes **AH1**, respectively. The first channel layers **114a** may have the same conductivity type as the substrate **111**. The first channel layers **114a** may include an intrinsic or undoped semiconductor material. First inner materials **115a** may be provided in the first active holes **AH1** including the first channel layers **114a**. The first inner materials **115a** may include, e.g., a semiconductor oxide, a semiconductor nitride, and/or an insulating material such as and an air gap. A first inner material and a first channel layer in a specific active hole may constitute a first sub-pillar. For example, the first channel layers **114a** and the first inner materials **115a** may constitute first sub-pillars **113a**, respectively.

Upper portions of the first inner materials **115a** of the first sub-pillars **113a** may be recessed. Semiconductor pads **SP** may be formed in regions where the first inner materials **115a** are recessed. The semiconductor pads **SP** may include the same material as the first channel layers **114a**. Upper portions

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of the first channel layers **114a** may surround corresponding ones of the semiconductor pads **SP**.

Referring to FIG. **16**, the second insulating materials **112a** and the first insulating materials may be additionally stacked alternately on the structure illustrated in FIG. **15**. Thereafter, second active holes **AH2** may be formed through the first and second insulating materials **112** and **112a** additionally stacked on the structure illustrated in FIG. **15**, e.g., in the direction perpendicular to the substrate **111**. The second active holes **AH2** may be formed on a region where the first active holes **AH1** are provided. The second active holes **AH2** may be formed to expose the first sub-pillars **113a**, e.g., the semiconductor pads **SP** of the first sub-pillars **113a**.

Second channel layers **114b** may be formed on inner surfaces of the second active holes **AH2**, respectively. The second channel layers **114b** may include the same material as the first channel layers **114a**. Second inner materials **115b** may be provided in the second channel layers **114b**, respectively. For example, the second inner materials **115b** may fill the second active holes **AH2** including the second channel layers **114a**. The second inner materials **115b** may include the same material as the first inner materials **114a**. A channel layer and an inner material in a specific second active hole may constitute a second sub-pillar. For example, the second channel layers **114b** and the second inner materials **115b** may constitute second sub-pillars **113b**, respectively.

Thereafter, e.g., as described with reference to FIGS. **9** to **13**, electrode dividing holes **EDH** may be formed, second insulating materials **112a** may be removed, information storage layers **116** may be conformally formed, a conductive layer **CM** may be formed, a planarization process may be performed, and a wordline cut **WL Cut** may be formed. And then, doping regions **311-313** may be formed, drains **320** may be formed, and bitlines **BL1** and **BL2** may be formed so that the structure illustrated in FIG. **14** may be achieved.

FIG. **17** illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. **3**. Referring to FIGS. **3** and **17**, the memory block **BLK1** includes structures extending in first to third directions.

The structure shown in FIG. **17** is similar to that described with reference to FIG. **4**, except that third insulating materials **112b** are provided between first insulating materials **112** and pillars **113**. According to an exemplary embodiment, first insulating materials **112** provided between conductive materials **CL1-CL8** have negative characteristics. Thus, the possibility of spreading may be reduced and/or prevented to, e.g., help enhance reliability of a nonvolatile memory device (**100** in FIG. 1).

A stress may be caused at a semiconductor channel by the semiconductor nitride. Accordingly, when the first insulating materials **112** including, e.g., semiconductor nitride, come in contact with a channel layer **114** used, e.g., a semiconductor channel, a stress may be applied to the channel layer **114**.

According to an exemplary embodiment, third insulating materials **112b** may be provided between the first insulating materials **112** including semiconductor nitride and the pillars **113** including the channel layer **114**. For example, the first insulating materials **112** may be isolated from other first insulating materials **112** by the third insulating materials **112b** to, e.g., reduce the possibility of and/or prevent a stress from being applied to the channel layer **114**. Thus, reliability of a nonvolatile memory device, e.g., device **100** in FIG. 1, may be enhanced.

FIGS. **18** and **20** illustrate cross-sectional views depicting stages in a procedure of forming the memory block **BLK1** described with reference to FIGS. **3** and **17**. Referring to FIG. **18**, second insulating materials **112a** and first insulating

materials **112** may be alternately stacked on a substrate **111** to form a stacked structure. For example, the second insulating material **112a** may be stacked on, e.g., directly on, the substrate **111**, and the first insulating material **112** may be stacked on the second insulating material **112a**. Thereafter, the first insulating material **112** may be stacked on the second insulating material **112a**, and the second insulating material **112a** may be stacked on the first insulating material **112**. The second insulating materials **112a** and the first insulating materials **113** may be alternately stacked to a specific height. According to an exemplary embodiment, the second insulating materials **112a** may include, e.g., a semiconductor oxide, and the first insulating materials **112** may include, e.g., a semiconductor nitride.

Active holes AH may be formed through the first and second insulating materials **112** and **112a** in a direction perpendicular to the substrate **111**. The active holes AH may be formed to expose the substrate **111**.

Third insulating materials **112b** may be formed, e.g., conformally formed, on inner surfaces of the active holes AH. The third insulating materials **112b** may include, e.g., the same material as the second insulating materials **112a**. For example, the third insulating materials **112b** may include a semiconductor oxide.

Thereafter, bottom portions of the third insulating materials **112b** may be removed. For example, the bottom portions of the third insulating materials **112b** may be removed to expose a top surface of the substrate **111**.

Channel layers **114** may be formed on the inner side surfaces of the third insulating materials **112b** and bottom surfaces of the active holes AH, respectively. Inner materials **115** may be provided in the channel layers **114**, e.g., to fill the active holes AH including the channel layers **114**. A channel layer and an inner material in a specific active hole may constitute a pillar. That is, the channel layers **114** and the inner materials **115** may constitute pillars **113**, respectively.

Referring to FIG. 19, electrode dividing holes EDH may be formed through the first and second insulating materials **112** and **112a** in a direction perpendicular to the substrate **111**. The electrode dividing holes EDH may be formed to expose the substrate **111**. The electrode dividing holes EDH may extend between the pillars **113** in a first direction. That is, the electrode dividing holes EDH may divide the first and second insulating materials **112** and **112a** in the first direction. From another standpoint, the electrode dividing holes EDH may divide the pillars **113**.

Referring to FIG. 20, among the first and second insulating materials **112** and **112a**, the second insulating materials **112** may be selectively removed. For example, the second insulating materials **112a** may be removed by injecting a material having an etching selectivity with respect to the first and second insulating materials **112** and **112a** through the electrode dividing holes EDH. Thus, a top surface of the substrate **111**, outer side surfaces of the pillars **113**, top surfaces and bottom surfaces of the first insulating materials **112**, and side surfaces of the first insulating materials **112** facing the pillars **113** may be exposed.

The third insulating materials **112b** may include the same material as the second insulating materials **112a**. A part of the second insulating materials **112b** may be removed at the same time as the second insulating materials **112a** are removed. For example, during the process of removing the second insulating materials **112a**, portions between the second insulating materials **112a** of the third insulating materials **112b** and the pillars **113** may be removed. For example, after the second insulating materials **112a** are removed, the portion between

the second insulating materials **112a** of the third insulating materials **112b** and the pillars **113** may be removed.

If the portion between the second insulating materials **112a** of the third insulating materials **112b** and the pillars **113** is removed, the third insulating materials **112b** may remain between the first insulating materials **112** and the pillars **113**.

Thereafter, as described with reference to FIGS. 11 to 13, information storage layers may be formed, e.g., conformally formed, a conductive layer CM may be removed, a planarization process may be performed, and a wordline cut WL Cut may be formed. And then, doping regions **311-313** may be formed, drains **320** may be formed, and bitlines BL1 and BL2 may be formed so that the structure illustrated in FIG. 14 may be achieved.

FIG. 21 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3. As illustrated in FIG. 21, according to the exemplary embodiment, that pillars **113** may include first sub-pillars **113a** and second sub-pillars **113b** on the first sub-pillars **113a**, and third insulating materials **112b** may be formed adjacent to the first sub-pillars **113a** and the second sub-pillars **113b**. The structure shown in FIG. 21 may be similar to that described with reference to FIGS. 14 and 17.

First insulating materials **112** may be provided between conductive materials CL1-CL8 have negative characteristics. Third insulating materials **112b** may be provided between the insulating materials **112** and first and second sub-pillars **113a** and **113b**. Thus, reliability of a nonvolatile memory device, e.g., device **100** in FIG. 1, may be enhanced.

First channel layers **114a** of the first sub-pillars **113a** may include the same material as the channel layers **114** described with reference to, e.g., FIG. 17. Second channel layers **114b** of the second sub-pillars **113b** may include the same material as the channel layers **114** described with reference to, e.g., FIG. 17.

First inner materials **115a** of the first sub-pillars **113a** may include the same material as the inner materials **115** described with reference to, e.g., FIG. 17. Second inner materials **115b** of the second sub-pillars **113b** may include the same material as the inner materials **115** described with reference to, e.g., FIG. 17.

Semiconductor pads SP may be provided on the first sub-pillars **113a**, respectively. First channel layers **114a** of the first sub-pillars **113a** and second channel layers **114b** of the second sub-pillars **113b** may be connected to each other through the semiconductor pads SP, respectively.

Among the conductive materials CL1-CM8, conductive materials having a height corresponding to that of the semiconductor pads SP, e.g., the fourth conductive pads CL4, the fifth conductive pad CL5, or the fourth and fifth conductive pads CL4 and CL5 may be used with and/or as dummy wordlines DWL.

The structure shown in FIG. 21 may be formed through similar steps as described with reference to FIGS. 15 and 16, except additional stages of, e.g., conformally forming third insulating materials **112b** on inner surfaces of first and second active holes AH1 and AH2 and recessing bottom portions of the third insulating materials **112b** may be performed.

FIG. 22 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3. Referring to FIGS. 3 and 22, the memory block BLK1 includes structures extending in first to third directions.

The structure shown in FIG. 22 is similar to that described with reference to FIG. 17, except that first information storage layers **116a** may be provided on outer side surfaces of the pillars **113**, e.g., outer surfaces of the channel layers **114**, and second information storage layers **116b** may be provided on

top and bottom surfaces of conductive materials CL1-CL8 and adjacent side surfaces of pillars 113.

According to an exemplary embodiment, first insulating layers 112 provided between the conductive materials CL1-CL8 may have negative characteristics. Third insulating materials 112b may be provided between the first insulating materials 112 and the pillars 113. Thus, reliability of a non-volatile memory device, e.g., device 100 in FIG. 1, may be enhanced.

FIG. 23 illustrates an enlarged view of a cell transistor CTa in FIG. 22. Referring to FIGS. 3, 22, and 23, a cell transistor CTa may include a region of pillars 113 adjacent to a fifth conductive material CL5 and first and second conductive storage layers 116a and 116b provided between the fifth conductive material CL5 and the pillars 113.

The first storage information layer 116a may be provided on outer side surfaces of the pillars 113. The first information storage layer 116a may include a first sub layer 117a and a second sub layer 118a. The first sub layer 117a may include, e.g., a thermal oxide and/or a semiconductor oxide. The second sub layer 118a may include a semiconductor nitride and/or a metal oxide (e.g., aluminum oxide, hafnium oxide, etc.).

The second information storages 116b may extend between conductive materials CL1-CL8 and the pillars 113. For example, the second information storages 116b may extend onto, e.g., extend across, top and bottom surfaces of the conductive materials CL1-CL8 from between the conductive materials CL1-CL8 and the first information storage layers 116a.

A channel layer 114 may act as a vertical body. The first sub layer 117a may act a tunneling insulating layer. The second sub layer 118a may act as a blocking insulating layer. The fifth conductive material CL5 may act as a gate or a control gate.

For example, the fifth conductive material CL5 acting as a gate (or control gate), the second information storage layer 116b acting as a blocking insulating layer, the second sub layer 118 acting as a charge storage layer, the first sub layer 117 acting as a tunneling insulating layer, and the channel layer 114 acting as a vertical body together may act as a cell transistor.

FIGS. 24 to 26 illustrate cross-sectional views of a procedure of forming the memory block BLK1 described with reference to FIGS. 3 and 22. Referring to FIG. 24, second insulating materials 112a and first insulating materials 112 may be alternately stacked on a substrate 111. For example, the second insulating material 112a may be stacked on, e.g., directly on, the substrate 111 and the first insulating layer 112 may be stacked on the second insulating material 112a. Thereafter, the first insulating layer 112 may be stacked on the second insulating material 112a, and the second insulating material 112a may be stacked on the first insulating layer 112. The second insulating materials 112a and the first insulating materials 112 may be alternately stacked to a specific height. According to an exemplary embodiment, the second insulating materials 112a may include, e.g., silicon oxide. The first insulating materials 112 may include, e.g., silicon nitride.

Active holes AH may be formed through the first and second insulating materials 112 and 112a in a direction perpendicular to the substrate 111. The active holes AH may be formed to expose the substrate 111.

Third insulating materials 112b may be formed, e.g., conformally formed, on inner surfaces of the active holes AH. The third insulating materials 112b may include the same material as the second insulating materials 112a. For example, the third insulating materials 112b may include

semiconductor oxide. Thereafter, bottom portions of the third insulating materials 112b may be removed. For example, the bottom portion of the third insulating materials 112b may be removed to expose the substrate 111.

First information storage layers 116a may be conformally formed on inner side surfaces of the third insulating materials 112b and bottom surfaces of the active holes AH. For example, a second sub layer 118a and a first sub layer 117a may be sequentially and conformally formed. Thereafter, bottom portions of the first information storage layers 116a may be recessed. For example, the bottom portions of the third insulating materials 112b may be recessed to expose the substrate 111.

Channel layers 114 may be conformally formed on inner side surfaces of the first information storage layers 116a and the bottom surfaces of the active holes AH. Inner materials 115 may be provided in the channel layers 114. A channel layer and an inner material in a specific active hole may constitute a pillar. For example, the channel layer 114 and the inner materials 115 may constitute pillars 113, respectively.

Referring to FIG. 25, electrode dividing holes EDH may be formed through the first and second materials 112 and 112a in a direction perpendicular to the substrate 111. The electrode dividing holes EDH may be formed to expose the substrate 111. The electrode dividing holes EDH may extend between the pillars 113 in a first direction. For example, the electrode dividing holes EDH may divide the first and second insulating materials 112 and 112a in the first direction. From another standpoint, the electrode dividing holes EDH may divide the pillars 113.

Referring to FIG. 26, the second insulating materials 112a may be selectively removed among the first and second insulating materials 112 and 112a. For example, the second insulating materials 112a may be removed by injecting a material having an etching selectivity with respect to the first and second insulating materials 112 and 112a through the electrode dividing holes EDH. Thus, a top surface of the substrate 111, outer side surfaces of the pillars 113, top surfaces and bottom surfaces of the first insulating materials 112, and side surfaces of the first insulating materials 112 facing the pillars 113 may be exposed.

Thereafter, as described with reference to FIGS. 11 to 13, second information storage layers 116b may be formed, e.g., conformally formed, a conductive layer CM may be formed, a planarization process may be performed, and a wordline cut WL Cut may be formed. And then, doping regions 311-313 may be formed, drains 320 may be formed, and bitlines BL1 and BL2 may be formed so that the structure illustrated in FIG. 22 may be achieved.

FIG. 27 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3. The structure shown in FIG. 27 is similar to that described with reference to FIG. 22, except pillars include first sub-pillars 113a and second sub-pillars 113b.

First insulating materials 112 provided between conductive materials CL1-CL8 may have negative characteristics. Third insulating materials 112b may be provided between the first insulating materials 112 and the first and second sub-pillars 113a and 113b. Thus, reliability of a nonvolatile memory device, e.g., device 100 in FIG. 1, may be enhanced.

First channel layers 114a of the first sub-pillars 113a may include the same material as the channel layers 114 described with reference to, e.g., FIG. 22. Second channel layers 114b of the second sub-pillars 113b may include the same material as the channel layers 114 described with reference to, e.g., FIG. 22.

First inner materials **115a** of the first sub-pillars **113a** may include the same material as the inner materials **115** described with reference to, e.g., FIG. **22**. Second inner materials **115b** of the second sub-pillars **113b** may include the same material as the inner materials **115** described with reference to, e.g., FIG. **22**.

Semiconductor pads SP may be provided on the first sub-pillars **113a**, respectively. First channel layers **114a** of the first sub-pillars **113a** and second channel layers **114b** of the second sub-pillars **113b** may be connected to each other through the semiconductor pads SP, respectively.

Among the conductive materials CL1-CM8, conductive materials having a height corresponding to that of the semiconductor pads SP, e.g., the fourth conductive pads CL4, the fifth conductive pad CL5, or the fourth and fifth conductive pads CL4 and CL5 may be used as dummy wordlines DWL.

The structure shown in FIG. **27** may be formed through similar steps as described with reference to FIGS. **15** and **16**, except for additional steps of, e.g., conformally forming third insulating materials **112b** on inner surfaces of first and second active holes AH1 and AH2, recessing bottom portions of the third insulating materials **112b**, conformally forming first information storage layers **116a** on bottom surfaces of the first and second active holes AH1 and AH2, and recessing bottom portions of the first information storage layers **116a**.

FIG. **28** illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. **3**. Referring to FIGS. **3** and **28**, the memory block BLK1 may include structures extending in first to third directions.

The structure shown in FIG. **28** is similar to that described with reference to FIG. **4**, except that first information storage layers **116a** are provided on outer side surfaces of the pillars **113** and second information storage layers **116b** are provided on top and bottom surfaces of the conductive materials CL1-CL8 and adjacent side surfaces of the pillars **113**.

FIG. **29** illustrates an enlarged view of a cell transistor CTb in FIG. **28**. Referring to FIGS. **3**, **28**, and **29**, the cell transistor CTb may include a fifth conductive material CL5, a region of pillars **113** adjacent to the fifth conductive material CL5, and the first and second information storage layers **116a** and **116b** provided between the fifth conductive material CL5 and the pillars **113**.

The first information storage layers **116a** may be provided on outer side surfaces of the pillars **113**. The first information storage layers **116a** may include a first sub layer **117a** and a second sub layer **118a**. The first sub layer **117a** may include, e.g., a thermal oxide and/or a semiconductor oxide. The second sub layer **118a** may include a semiconductor nitride and/or a metal oxide (e.g., aluminum oxide, hafnium oxide, etc.).

The second information storages **116b** may extend between conductive materials CL1-CL8 and the pillars **113**. For example, the second information storages **116b** may extend onto top and bottom surfaces of the conductive materials CL1-CL8 from between the conductive materials CL1-CL8 and the first information storage layers **116a**. The second information storage layer **116b** may include a semiconductor oxide.

A channel layer **114** may act as a vertical body. The first sub layer **117a** may act a tunneling insulating layer. The second sub layer **118a** may act as a charge trapping layer. The second storage information layer **116b** may act as a blocking insulating layer. The fifth conductive material CL5 may act as a gate or a control gate.

For example, the fifth conductive material CL5 acting as a gate (or control gate), the second information storage layer **116b** acting as a blocking insulating layer, the second sub

layer **118** acting as a charge trapping layer, the first sub layer **117** acting as a tunneling insulating layer, and the channel layer **114** acting as a vertical body may act as a cell transistor.

Referring to FIGS. **28** and **29**, the first information storage layers **116a** may be provided between the first insulating materials **112** and the pillars **113**. The first information storage layers **116a** may include a first sub layer **117a** provided on outer side surfaces of the pillars **113** and a second sub layer **118a** provided on an outer side surface of the first sub layer **117a**. According to an exemplary embodiment, the first sub layer **117a** includes a semiconductor oxide and the second sub layer **118a** includes a semiconductor nitride. The first sub layer **117a** including the semiconductor oxide may be provided between the first insulating materials **112** and the pillars **113**. For example, the pillars **113** may be isolated from the second sub layer **118a** and the first insulating materials **112** by the first sub layer **117a**.

The first insulating materials **112** provided between the conductive materials CL1-CL8 may have negative characteristics. In addition, the first sub layer **117a** may be provided between the first insulating materials **112** and the pillars **113**. Thus, reliability of a nonvolatile memory device, e.g., device **100** in FIG. **1**, may be enhanced.

FIGS. **30** to **32** illustrate cross-sectional views of a procedure of forming the memory block BLK1 described with reference to FIGS. **3** and **28**. Referring to FIG. **30**, second insulating materials **112a** and first insulating materials **112** may be alternately stacked on a substrate **111**. For example, the second insulating material **112a** may be stacked on, e.g., directly on, the substrate **111** and the first insulating layer **112** may be stacked on the second insulating material **112a**. The first insulating layer **112** may be stacked on the second insulating material **112a**, and the second insulating material **112a** may be stacked on the first insulating layer **112**. The second insulating materials **112a** and the first insulating materials **112** may be alternately stacked to a specific height. The second insulating materials **112a** may include a semiconductor oxide and the first insulating materials **112** may include a semiconductor nitride.

Active holes AH may be formed through the first and second insulating materials **112** and **112a** in a direction perpendicular to the substrate **111**. The active holes AH may be formed to expose the substrate **111**.

First information storage layers **116a** may be formed, e.g., conformally formed, on inner side surfaces of the active holes. For example, the second sub layer **118a** and the first sub layer **117a** may be sequentially and conformally formed. Thereafter, bottom portions of the first information storage layers **116a** may be removed. For example, the bottom portions of the third insulating materials **112b** may be removed to expose a top surface of the substrate **111**.

Channel layers **114** may be conformally formed on inner side surfaces of the first information storage layers **116a** and bottom surfaces of the active holes AH. Inner materials **115** may be provided in the channel layers **114**. One channel layer **114** and one inner material **115** in a specific hole may constitute one pillar **113**. That is, the channel layers **114** and the inner materials **115** constitute pillars **113**, respectively.

Referring to FIG. **32**, electrode dividing holes EDH may be formed through the first and second insulating materials **112** and **112a** in the direction perpendicular to the substrate **111**. The electrode dividing holes EDH may be formed to expose the substrate **111**. The electrode dividing holes EDH may extend between the pillars **113** in a first direction. For example, the electrode dividing holes EDH may divide the first and second insulating materials **112** and **112a** in the first

direction. From another standpoint, the electrode dividing holes EDH may divide the pillars 113.

Referring to FIG. 32, the second insulating materials 112a may be selectively removed among the first and second insulating materials 112 and 112a. For example, the second insulating materials 112a may be removed by injecting a material having an etching selectivity with respect to the first and second insulating materials 112 and 112a through the electrode dividing holes EDH. Thus, a top surface of the substrate 111, outer side surfaces of the pillars 113, top surfaces and bottom surfaces of the first insulating materials 112, and side surfaces of the first insulating materials 112 facing the pillars 113 may be exposed.

Thereafter, as described with reference to FIGS. 11 to 13, second information storage layers 116b may be conformally formed, a conductive layer CM may be formed, a planarization process may be performed, and a wordline cut WL Cut may be formed. And then, doping regions 311-313 may be formed, drains 320 may be formed, and bitlines BL1 and BL2 may be formed so that the structure illustrated in FIG. 28 may be achieved.

FIG. 33 illustrates another exemplary embodiment of a cross-sectional view taken along the line I-I' in FIG. 3. The structure shown in FIG. 33 is similar to that described with reference to FIG. 28, except pillars includes first sub-pillars 113a and second sub-pillars 113b.

First insulating materials 112 provided between conductive materials CL1-CL8 may have negative characteristics. In addition, first information storage layers 116a may be provided between the first insulating materials 112 and first and second sub-pillars 113a and 113b. Thus, reliability of a nonvolatile memory device, e.g., device 100 in FIG. 1, may be enhanced.

First channel layers 114a of the first sub-pillars 113a may include the same material as the channel layers 114 described with reference to, e.g., FIG. 28. Second channel layers 114b of the second sub-pillars 113b may include the same material as the channel layers 114 described with reference to, e.g., FIG. 28.

First inner materials 115a of the first sub-pillars 113a may include the same material as the inner materials 115 described with reference to, e.g., FIG. 28. Second inner materials 115b of the second sub-pillars 113b may include the same material as the inner materials 115 described with reference to, e.g., FIG. 28.

Semiconductor pads SP may be provided on the first sub-pillars 113a. The first channel layers 114a of the first sub-pillars 113a and the second channel layers 114b of the second sub-pillars 113b may be connected to each other through the semiconductor pads SP, respectively.

Among the conductive materials CL1-CL8, conductive materials having a height corresponding to that of the semiconductor pads SP, e.g., the fourth conductive pads CL4, the fifth conductive pad CL5, or the fourth and fifth conductive pads CL4 and CL5 may be used as dummy wordlines DWL.

The structure shown in FIG. 33 may be formed through similar stages as described with reference to FIGS. 15 and 16, except for additional stages of e.g., forming the first information storage layers 116a on inner surfaces of first and second active holes AH1 and AH2 and recessing bottom portions of the first information storage layers 116a.

FIG. 34 illustrates a block diagram of a memory system 1000 according to an exemplary embodiment. As illustrated, the memory system 1000 may include a nonvolatile memory device 1100 and a controller 1200.

The nonvolatile memory device 1100 may have the same configuration as the nonvolatile memory device 100

described with reference to FIGS. 1 to 33 and may operate the same as the nonvolatile memory device 100. For example, the nonvolatile memory device 1100 may include conductive materials CL1-CL8 and first insulating materials 112 that are alternately stacked on a substrate (111 in FIGS. 3 to 33). The nonvolatile memory device 1100 may include the first insulating materials 112 having a semiconductor nitride included therein. The nonvolatile memory device 1100 may further include a semiconductor oxide provided between the first insulating materials 112 and pillars 113. The semiconductor oxide may be, e.g., may form, third insulating materials 112b or first sub materials 117a. Thus, the possibility of spreading and/or stress may be reduced and/or prevented so that, e.g., reliability of the nonvolatile memory device 1100 and reliability of the memory system 1000 including the nonvolatile memory device 1100 may be increased.

The controller 1200 may be connected to a host and the nonvolatile memory device 1100. In response to a request from the host, the controller 1200 may be configured to access the nonvolatile memory device 1100. For example, the controller 1200 may control the read, write, erase, and background operations of the nonvolatile memory device 1100. The controller 1200 may be configured to provide interface between the nonvolatile memory device 1100 and the host. The controller 1200 may be configured to drive firmware for controlling the nonvolatile memory device 1100.

The controller 1200 may be configured to supply a control signal CTRL and an address ADDR to the nonvolatile memory device 1100. The controller 1200 may be configured to exchange data DATA with the nonvolatile memory device 1100.

The controller 1200 may further include well-known elements such as, e.g., a random access memory (RAM), a processing unit, a host interface, and/or a memory interface. The RAM may be used as at least one of a working memory of the processing unit, a cache memory between the nonvolatile memory device 1100 and the host, and a buffer memory between the nonvolatile memory device 1100 and the host. The processing unit may control the overall operation of the controller 1200.

The host interface may include a protocol for data exchange between the host and the controller 1200. For example, the host interface may be configured to communicate with an external entity, e.g., a host through at least one of various interface protocols such as a Universal Serial Bus (USB) protocol, a Multimedia Card (MMC) protocol, a Peripheral Component Interconnection (PCI) protocol, a PCI-Express (PCI-E) protocol, an Advanced Technology Attachment (ATA) protocol, a Serial-ATA (SATA) protocol, a Parallel-ATA (PATA) protocol, a Small Component Small Interface (SCSI) protocol, an Enhanced Small Disk Interface (ESDI) protocol, and an Integrated Drive Electronics (IDE) protocol.

The memory system 1000 may be configured to further include an error correction block. The error correction block may be configured to detect and correct the error of data read from the nonvolatile memory device 1100 with an error correction code (ECC). For example, the error correction block may be provided as the element of the controller 1200. The error correction block may be provided as an element of the nonvolatile memory device 1100.

The controller 1200 and the nonvolatile memory device 1100 may be integrated into one semiconductor device. For example, the controller 1200 and the nonvolatile memory device 1100 may be integrated into one semiconductor device to configure a memory card. The controller 1200 and the nonvolatile memory device 1100 may be integrated into one

semiconductor device to configure a memory card such as a PC card (Personal Computer Memory Card International Association (PCMICA)), a compact flash card (CF), a smart media card (SM, SMC), a memory stick, a multimedia card (MMC, RS-MMC, MMCmicro), an SD card (SD, miniSD, microSD, SDHC), and a universal flash memory device (UFS).

The controller **120** and the nonvolatile memory device **1100** may be integrated into one semiconductor device to configure, e.g., a solid state drive (SSD). The semiconductor drive (SSD) may include a storage unit configured to store data in a semiconductor memory. When the memory system **1000** is used as the solid state drive (SSD), the operating speed of the host connected to the memory system **1000** may be dramatically improved.

As another example, the memory system **1000** may be provided as one of various elements for electronic devices such as computers, Ultra Mobile PCs (UMPCs), workstations, net-books, Personal Digital Assistants (PDAs), portable computers, web tablets, wireless phones, mobile phones, smart phones, e-books, Portable Multimedia Players (PMPs), portable game machines, navigation devices, black boxes, digital cameras, Digital Multimedia Broadcasting (DMB) players, digital audio recorders, digital audio players, digital picture recorders, digital picture players, digital video recorders, digital video players, devices for transmitting/receiving information at a wireless environment, one of various electronic devices configuring a home network, one of various electronic devices configuring a computer network, one of various electronic devices configuring a telematics network, RFID devices, and one of various elements configuring a computing system.

According to an exemplary embodiment, the nonvolatile memory device **1100** or the memory system **1000** may be packaged as one of various types to be subsequently embedded. For example, the nonvolatile memory device **1100** or the memory system **1000** may be packaged by one of PoP (Package on Package), Ball grid arrays (BGAs), Chip scale packages (CSPs), Plastic Leaded Chip Carrier (PLCC), Plastic Dual In-Line Package (PDIP), Die in Waffle Pack, Die in Wafer Form, Chip On Board (COB), Ceramic Dual In-Line Package (CERDIP), Plastic Metric Quad Flat Pack (MQFP), Thin Quad Flatpack (TQFP), Small Outline (SOIC), Shrink Small Outline Package (SSOP), Thin Small Outline (TSOP), Thin Quad Flatpack (TQFP), System In Package (SIP), Multi Chip Package (MCP), Wafer-level Fabricated Package (WFP), and Wafer-Level Processed Stack Package (WSP).

FIG. **35** illustrates a block diagram of an application example of the memory system **1000** in FIG. **34**. As illustrated, a memory system **2000** may include a nonvolatile memory device **2100** and a controller **2200**. The nonvolatile memory device **2100** may include a plurality of nonvolatile memory chips. The nonvolatile memory chips may be divided into a plurality of groups. Each group of the nonvolatile memory chips may be configured to communicate with the controller **2200** through one common channel. In FIG. **33**, it is illustrated that the nonvolatile memory chips may communicate with the controller **2200** through first to kth channels CH1-CHk.

Each of the nonvolatile memory chips may have a similar configuration as the nonvolatile memory device **100** described with reference to FIG. **1** and may operate the same as the nonvolatile memory device **100**. For example, the nonvolatile memory chip may include conductive materials CL1-CL8 and first insulating materials **112** that are alternately stacked on a substrate (**111** in FIGS. **3** to **33**), and the first

insulating materials **112** may include a semiconductor nitride. The nonvolatile memory chip may further include a semiconductor oxide provided between the first insulating materials **112** and pillars **113**. The semiconductor oxide may be third insulating materials **112b** or first sub materials **117a**. Thus, the possibility of spreading and/or stress may be reduced and/or prevented to, e.g., increase the reliability of the nonvolatile memory device **1100** and reliability of the memory system **1000** including the nonvolatile memory device **1100**.

In FIG. **33**, it is described that a plurality of nonvolatile memory chips are connected to one channel. However, embodiments are not limited thereto. For example, it will be understood that the memory system **2000** may be modified such that one nonvolatile memory chip is connected to one channel.

FIG. **36** illustrates a block diagram of a computing system **300** including the memory system **2000** described with reference to FIG. **35**. As illustrated, the computing system **3000** may include a central processing unit (CPU) **3100**, a random access memory (RAM) **3200**, a user interface **3300**, a power supply **3400**, and a memory system **2000**.

The memory system **2000** may be electrically connected to the CPU **3100**, the RAM **3200**, and the power supply **3400** through a system bus **3500**. Data provided through the user interface **3300** or processed by the CPU **3100** may be stored in the memory system **2000**.

In FIG. **36**, it is illustrated that the nonvolatile memory device **2100** is connected to the system bus **3500** through the controller **2200**. However, embodiments are not limited thereto. For example, the nonvolatile memory device **2100** may be configured to be directly connected to the system bus **3500**.

In FIG. **36**, it is described that the memory system **2000** described with reference to FIG. **33** may be provided in the computing system **3000**. However, embodiments are not limited thereto. For example, the memory system **2000** may be replaced with the memory system **1000** described with reference to FIG. **32**. The computing system **3000** may be configured to include both the memory systems **1000** and **2000** described with reference to FIGS. **32** and **33**.

As described so far, semiconductor nitrides may be provided between conductive materials constituting gates or control gates of memory cell transistors as interlayer dielectrics. Thus, the possibility of spreading caused by a difference in threshold voltage between the memory cell transistors may be reduced to enhance reliability of a nonvolatile memory device.

Example embodiments have been disclosed herein, and although specific terms are employed, they are used and are to be interpreted in a generic and descriptive sense only and not for purpose of limitation. In some instances, as would be apparent to one of ordinary skill in the art as of the filing of the present application, features, characteristics, and/or elements described in connection with a particular embodiment may be used singly or in combination with features, characteristics, and/or elements described in connection with other embodiments unless otherwise specifically indicated. Accordingly, it will be understood by those of skill in the art that various changes in form and details may be made without departing from the spirit and scope of the present invention as set forth in the following claims.

What is claimed is:

1. A nonvolatile memory device, comprising:
a substrate;
a stacked structure including conductive materials and first insulating materials, the conductive materials and the first insulating materials being alternately stacked on the substrate;
a plurality of pillars in contact with the substrate, the pillars extending through the stacked structure in a direction perpendicular to the substrate;
blocking insulating layers between the conductive materials and the first insulating materials; and
second insulating materials between each of the first insulating materials and each of the pillars such that each of the first insulating materials is spaced apart from each of the pillars, each of the second insulating material contacting only one of the first insulating materials, wherein the first insulating materials consist of silicon nitride.
2. The nonvolatile memory device as claimed in claim 1, wherein the blocking insulating layers extend onto top and bottom surfaces of the conductive materials from between the conductive materials and the pillars.
3. The nonvolatile memory device as claimed in claim 1, further comprising:
tunneling insulating layers on outer side surfaces of the pillars; and
charge trapping layers on outer side surfaces of the tunneling insulating layers,
wherein the blocking insulating layers extend onto top and bottom surfaces of the conductive materials from between the conductive materials and the charge trapping layers.
4. The nonvolatile memory device as claimed in claim 1, wherein each of the pillars includes a silicon layer.
5. A nonvolatile memory device, comprising:
a substrate;
a stacked structure including conductive materials and first insulating materials, the conductive materials and the first insulating materials being alternately stacked on the substrate, and the first insulating materials consisting of silicon nitride;
a plurality of pillars in contact with the substrate, the pillars extending through the stacked structure in a direction perpendicular to the substrate;
second insulating materials between each of the first insulating materials and each of the pillars such that each of the first insulating materials is spaced apart from each of the pillars, each of the second insulating material contacting only one of the first insulating materials;

- first silicon oxide layers on outer side surfaces of the pillars, the first silicon oxide layers extending through the stacked structure in the direction perpendicular to the substrate;
charge trapping layers on outer side surfaces of the first silicon oxide layers, the charge trapping layers extending through the stacked structure in the direction perpendicular to the substrate; and
second silicon oxide layers disposed between the conductive materials and the charge trapping layers and extending onto top and bottom surfaces of the conductive materials between the conductive materials and the first insulating materials.
6. The nonvolatile memory device as claimed in claim 5, wherein each of the pillars includes a silicon layer.
 7. The nonvolatile memory device as claimed in claim 5, wherein the first insulating materials are in direct contact with the charge trapping layers.
 8. A nonvolatile memory device, comprising:
a stacked structure on a substrate, the stacked structure including conductive materials and first insulating materials alternately stacked on the substrate, and the first insulating materials consisting of silicon nitride;
a plurality of pillars in contact with the substrate, the pillars extending through the stacked structure in a direction perpendicular to the substrate;
second insulating materials between each of the first insulating materials and each of the pillars such that each of the first insulating materials is spaced apart from each of the pillars, each of the second insulating material contacting only one of the first insulating materials;
first silicon oxide layers on outer side surfaces of the pillars, the first silicon oxide layers extending through the stacked structure in the direction perpendicular to the substrate;
charge trapping layers on outer side surfaces of the first silicon oxide layers, the charge trapping layers extending through the stacked structure in the direction perpendicular to the substrate; and
second silicon oxide layers disposed between the conductive materials and the charge trapping layers and extending onto top and bottom surfaces of the conductive materials between the conductive materials and the first insulating materials.
 9. The nonvolatile memory device as claimed in claim 8, further comprising bitlines connected to the plurality of pillars.
 10. The nonvolatile memory device as claimed in claim 1, wherein the second insulating materials include silicon oxide.

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